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THE COMPLETE

PRACTICAL MACHINIST:

EMBRACING

LATHE WORK, VISE WORK,

Drills and Drilling, Taps and Dies, Hardening and Tempering, The Making and Use of Tools, etc., etc.

BY

JOSHUA ROSE.

ILLUSTRATED BY 130 ENGRAVINGS.

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PREFACE.

THE education of the machinist in the science governing the daily practice of his art has not received its proper share of attention at the hands of those authors who have written books upon mechanical subjects: and the artisan is, in consequence, deprived of the aid derivable from the experience of the thousands who have trodden the same path before him. Hence it takes years of practice and observation to acquire knowledge which could be gained in a comparatively short space of time by the aid of a little book-learning.

To converse intelligently with the artisan, it is necessary to employ language and terms with which he is familiar; and in cases where calculations are required, they should be of as simple a nature as possible, because the practical machinist is not usually versed in algebra; and if he finds that the information of which he is in pursuit is treated only in formulæ whose meanings are a mystery to him, he becomes discouraged and abandons the task of their elucidation. When, on the other hand, the mechanic is encour-

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aged by the easy acquirement of the desired knowledge, it proves an incentive which leads him to higher paths of study, into the pursuit of which he had at first no idea of entering.

Practical workmanship is not a mere matter of accustoming the fingers to perform mechanical movements; but is governed by a series of distinct principles, simple and complex, the employment of which depends at all times upon the perception and judgment of the artisan. Nearly the whole distinction between an expert and an indifferent workman consists in their relative capability to perceive the principles applicable to particular work, and in their readiness in overcoming the innumerable little obstacles which present themselves, rendering a deviation, at times, from a common rule either highly advantageous or absolutely necessary.

The inexperienced or unobservant mechanic frequently fails to recognize the very principles he applies to his work, although conscious of a large class of conditions under which he would proceed by the same method; because experience has forced it upon him as indispensable in such cases. Being dependent upon the information which he may be able to gather from the particular pieces of work which chance to fall to his lot, and to such scraps of disjointed instruction as a fellow-workman may feel disposed to impart, it often occurs that, when he encounters a difficulty, the more experienced hand who helps him

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out of it neglects to explain the principle governing the means by which the difficulty was overcome, so that the uninitiated gains nothing by the experience, and fails to perceive the numerous applications of similar remedies to parallel obstacles.

The machinist stands related to iron as the carpenter, joiner, cabinet maker, wheelwright, etc., do to wood, with the disadvantage that he has to design and determine the shapes and temper of his tools, which vary so much (to suit the work) that the tool suitable for one piece may be totally inadequate to perform the same service upon another, although the proportions, the texture, and the metals may be alike in both instances. We cannot, therefore, tell a good machinist by his tools, unless we know for what particular piece of work those tools were used. Nor can a machinist be judged from his shavings, because there are many kinds of work for which a tool keen enough to cut a thick and clean shaving cannot be used to advantage. Even the speeds, given in mechanical books, at which to cut metals tend to mislead, because the nature and size of the work, the depth and nature of the cut, and numerous other influences render the variation of the cutting speed at times one-third greater or less than the given speed. A knowledge, however, of the general rules, together with an intelligent understanding of the principles governing the exceptions and deviations, will enable the artisan, when a difficulty arises, to at once perceive

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its precise cause, and to apply an adequate remedy, the conditions only requiring to be understood to render the application of the principles governing them palpably necessary and easy of accomplishment; thus rendering the learning of the trade more a matter of understanding and less a matter of unintelligent labor.

The aim, therefore, of the author of this book is to develop from the promiscuous practice of the workshop its inherent science, and to present it to the mechanic so arranged that he will find each formula the natural sequence to its predecessor; and while explaining its positive conditions, to so present its negative ones that the mind will instinctively seek the remedy which its successor will supply.

A large portion of the contents of the following pages has originally appeared, under the author's name, and during the past two years, in the *Scientific American* and the *Scientific American Supplement* of New York. The various subjects are here, however, treated upon more fully than they were in these journals, while a large quantity of entirely new matter has been added.

NEW YORK, July 15th, 1876.

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THE

COMPLETE PRACTICAL MACHINIST.

CHAPTER I.

LATHE AND MACHINE TOOLS.

THE principal consideration in determining the proper shape of a cutting tool, for use in a lathe or machine, is where it shall have the rake necessary to make it keen enough to cut well, and yet be kept as strong as possible; and this is governed, in a large degree, by the nature of the work on which it is to be used. It is always desirable, circumstances permitting, to place nearly all the rake or keenness on the top face of the tool, as shown in Fig. 1;

Fig. 1.

the line *a* representing the top face, and its rake being its incline in the direction of the arrow. In those cases (to be hereafter specified) in which top rake is, from the nature of the work to be cut, impracticable, it must be taken off and the tool given the necessary keenness by increasing the rake or angle of the bottom or side faces in the direc-

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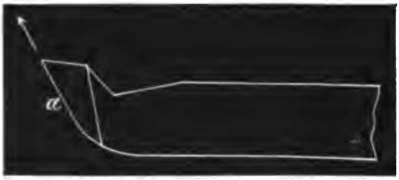
tion shown in Fig. 2, in which the line *a* represents a side or bottom face of the tool, its amount of rake being denoted by its angle in the direction of the arrow.

Fig. 2.



These top and side faces, taken one in conjunction with the other, form a wedge, and all machine tools are nothing more than cutting wedges, the duty performed by the respective faces depending, first, upon the keenness of the general outline of the top and bottom faces, and secondly, upon the position, relative to the work, in which the tool is held and applied.

The strain sustained by the top face is not alone that due to the severing of the metal, but that, in addition, which is exerted to break or curl the shaving, which would, if not obstructed by the top face, come off in a straight line, like a piece of cord being unrolled from a cylinder; but on coming into contact with the face of the tool (immediately after it has left the cutting edge), it is forced, by that face, out of the straight line and takes circular form of more or less diameter according to the amount of top rake possessed by the tool. The direction of the whole strain upon the top face is at a right angle to it, as denoted in Fig. 3 by the line D, *a* being the work, B the tool, and *c* the shaving. It will be readily perceived, then, that if a tool possessing so much top rake is held far out from the tool post or clamp, or is slight in body, any springing of the body of the tool, arising from the pressure due to the cut, will cause the tool point to take a deeper cut, and that the tendency of the strain upon the top face is to draw the tool deeper into its cut. A plain cut (either

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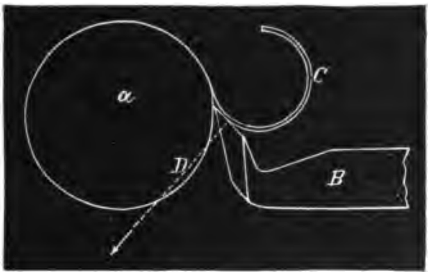
inside or outside) admits of the use of a maximum of top rake and of a minimum of bottom rake in all cases when the tool is not liable to spring.

Were the strain upon the tool equal in force at all times during the cut, the spring would also be equal, and the cut, therefore, a smooth one; but in taking a first cut, there may be, and usually is, more metal to be cut off the work in one place than in another; besides which there are inequalities in the texture of the metal, so that when the harder parts come into contact with the tool, it springs more and cuts deeper than it does when cutting the softer parts, and therefore leaves the face of the work uneven.

Fig. 3.



The main duty performed by the bottom face of the tool is to support the cutting edge, and the amount of rake it possesses is not, under ordinary circumstances, of very great consequence, so that it be sufficient to well clear, and not rub against the work. It is always desirable, however, to give it as little rake, over and above clearance, as possible, to avoid weakening the cutting part of the tool.

When, in consequence of the top face having but very little rake, it becomes necessary to make the general outline of the tool keen by the application of the maximum of side or bottom rake, the tool becomes proportionately weak, as is shown in Fig. 4; in which *a* represents the work, B the tool, *c* the shaving, and D the direction of

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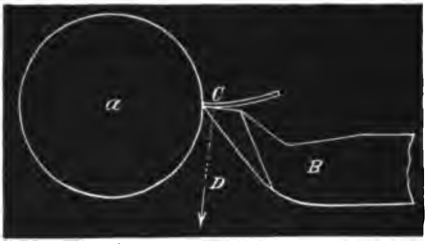
the strain placed upon the top face of the shaving, from which, it will be noted, that the cutting edge is comparatively weak, and hence, liable to break.

Fig. 4.



It follows, then, that if two tools are placed in position to take an equal cut off similar work, that which possesses the most top rake, while receiving the least strain from the shaving, receives it in a direction the most likely to spring it into its cut. It must not, therefore, be used upon any work having a tendency to draw the tool in, nor upon work to perform which the tool must stand far out from the tool post, for in either case it will spring into its cut.

Especially is this likely to occur if the cut has a break in it with a sharply defined edge, such, for example, as turning a shaft with a dovetailed groove in it. Taking all these considerations into account, we arrive at the tool shown in Fig. 5, as representing the most desirable amount of top and bottom rake for ordinary purposes on light work; such a tool is not, however, adapted to taking very heavy cuts, for which duty the top face of the tool is given what is termed side rake.

Fig. 5.

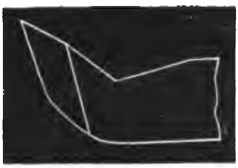


Fig. 6 represents a tool having a maximum of side rake, and therefore designed for very heavy duty, and to be held as close to the tool post as possible. The amount of power required to feed a lathe or other tool into its cut, at the

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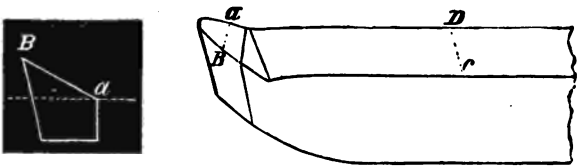
Fig. 6.

same time that the tool is cutting, is considerable when a heavy cut is being taken; and the object of side rake is not only to make the tool more keen without sacrificing its strength, but to relieve the feed screw or gearing of part of this strain by giving the tool a tendency to feed along and into its cut, which is accomplished by side rake, thus:

Suppose Fig. 7 to be a cross or end section of a tool having side rake, that is:

Fig. 7.



The line B representing in both cases the cutting edge, and from *a* to B the line of angle forming the side rake. This form gives the tool a tendency to feed itself along and into the cut, the cause of which is that the pressure upon the top face, B *a* (the result of its having to bend the shaving out of the straight line), is placed, in consequence of the side incline, more upon the side and less upon the top of the face. It has, in fact, followed the

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direction of the rake, decreasing its tendency to run, or spring, in (as shown in Fig. 3), with a corresponding gain in the above-mentioned inclination to feed itself along, or into, its lateral cut.

When side rake is called into use, a corresponding amount of front rake must be dispensed with, or its tendency to feed itself becomes so great that it will swing round, using the tool post as a centre, and (feeding rapidly into the cut) spring in and break from the undue pressure, particularly if the lathe or machine has any play in the slides. So much side rake may be given to a tool that it will feed itself without the aid of any feed motion, for the force required to bend the shaving (in heavy cuts only) will react upon the tool, forcing it up and into its cut, while the amount of bottom rake, or clearance as it is sometimes called, may be made just sufficient to permit the tool to enter its cut to the required thickness of shaving or feed and no more; and it will, after the cut is once begun, feed itself and stop of itself when the cut is over. But to grind a tool to this exactitude is too delicate an operation for ordinary practice. The experiment has, however, been successfully tried; but it was found necessary to have the slides of the lathe very nicely adjusted, and to take up the lost motion in the cross-feed screw.

For roughing out and for long continuous cuts, this tool is the best that can be used; because it presents a keen cutting edge to the metal, and the cutting edge receives the maximum of support from the steel beneath or behind it. It receives less strain from the shaving than any other; and will, in consequence of these virtues combined, take a heavier cut, and stand it longer, than any other tool; but it is not so good for taking a finishing cut as one having front rake, as shown in Fig. 5.

Having determined the position of the requisite rake, the next consideration is that of the proper form of the cutting edge, the main principles of which are as follows:

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ROUND-NOSED TOOLS,

such as shown in Fig. 8, have more cutting edge to them

Fig. 8.

(the depth of the cuts being equal) than the straighter-nosed ones, such as shown in Fig. 9, receiving as the result

Fig. 9.

more strain from, and becoming more liable to run into or out from, the cut. If sufficient rake is given to the tool to obviate this defect, it will, under a heavy cut, spring in. It is, however, well adapted to cutting out curves, or taking finishing cuts on wrought-iron work, which is so strong and stiff as not to spring away from it, because it can be used with a coarse feed without leaving deep or rough tool or feed marks; it should, however, always be used with a slow speed. On coming into contact with the scale or skin of the metal, in case the work will not true up, it is liable to spring away from its cut. If held far out from the tool post, it is apt to jar or chatter; and unless the work and the tool are both firmly held, it is liable to cut deeper into the softer than into the harder parts of the metal. The angles or sides of a cutting tool must not of necessity be quite flat (unless for use on slight work, as rods or spindles), but slightly curved, and in all cases rounded at the point, as in the tool shown in Fig. 9. If the angles

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were left flat and the point sharp, the tool would leave deep and ragged feed marks; the extreme point, wearing away quickly, would soon render the tool too dull for use, and the point would be apt to break.

For finishing small wrought-iron work it should be ground, as shown in Fig. 10, being far preferable to the

Fig. 10.

square-nosed finishing tools sometimes used for that purpose, since such tools do not turn true but follow the texture of the metal, cutting deepest in the softer parts, especially when the tool edge becomes the least dulled from use. It should be used with a quick speed and fine feed. On turning work of one inch and less in diameter, it is an excellent roughing tool, and with the addition of a little side rake is, for work of two inches and less diameter, as good a tool for roughing out as any that can be used.

SQUARE-NOSED TOOLS.

Square-nosed tools, such as shown in Fig. 11, should never be used upon wrought-iron, steel, or brass, for a broad cutting surface running parallel with the line of feed will always, upon either of these metals, cause the

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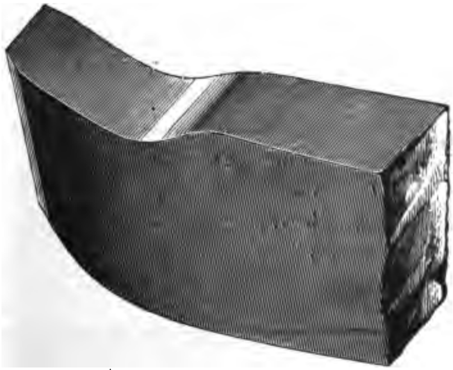
tool point to spring into the softer parts and to spring away from the harder parts, and, if the tool is liable to spring, in most cases, to dig into the work. Upon cast-iron work, however, such a tool will work to great advantage either for roughing out or finishing. It should be set so that its square nose is placed quite parallel with the work;

Fig. 11.



the feed for finishing purposes being almost as broad as the nose of the tool itself, or say three revolutions of the lathe per inch of tool travel. It should be fed very evenly, because all tools possessing a broad cutting surface are subservient to spring, which spring is, in this case, in a direction to deepen the cut; so that, if more cut is taken at one revolution or stroke than at another, the one cut will be deeper than the other. They are likewise liable to jar or tremble, the only remedy for which is to grind away some of the cutting face or edge, making it narrower. For taking finishing cuts on cast-iron, more top rake may be given to the tool than is employed to rough it out, unless the metal to be cut is very hard; else the metal will be found, upon inspection, to have numerous small holes on the face that has been cut, appearing as though it were very porous. This occurs

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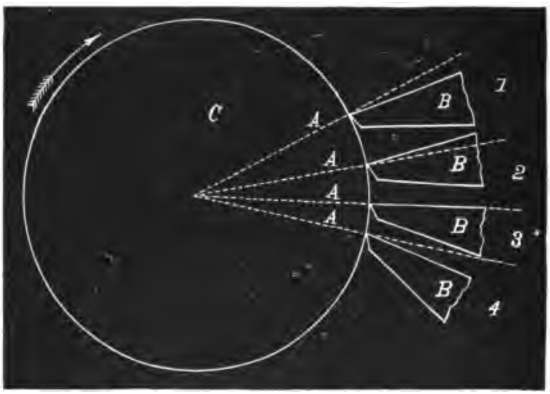
because the tool has not cut keenly enough, and has broken the grain of the metal out a little in advance of the cut, in consequence of an undue pressure sustained by the metal at the moment of its being severed by the tool edge.

The angle of the top and of the bottom face of a tool does not determine whether it shall act as a scraping or cutting tool, but merely affects its capability of withstanding the strain and wear due to severing the metal which it cuts. Nor is there any definite angle at which the top face, B, to the work converts the edge from a cutting to a scraping one. A general idea may, however, be obtained by reference to Fig. 12, the line A being in each case one drawn from the centre of the work to the point of contact between the tool edge and the work, C being the work, and B the tool. It will be observed that the angle of the top face of the tool varies in each case with the line A. In

Fig. 12.



position 1, the tool is a cutting one; in 2, it is a scraper; in 3, it is a tool which is a cutter and scraper combined, since it will actually perform both functions at one and the same time; and in 4, it is a good cutting tool, the shapes and angles of the tools being the same in each case.

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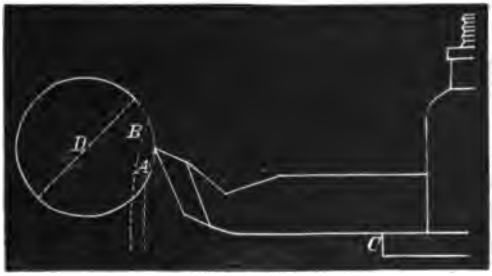
HOLDING TOOLS.

All tools should be fastened or held so that their cutting edges are as near the tool post as possible, so as to avoid their springing, and to check as far as possible their giving way to the cut, in consequence of the play there may be in the slides of the tool rest; but if, from the nature of the work to be performed, the tool must of necessity stand out far from the tool post, we should give the tool but little top rake, and be sure not to place it above the horizontal centre of the work. The point or fulcrum, off which the spring of a lathe tool takes place, is denoted in Fig. 13,

Fig. 13.



by C, the dotted line A indicating the direction in which the point of the tool would spring, and the dotted line B representing the direction in which it would spring if it stood at B; from which it becomes apparent that, if placed at the point B, the spring would be more in a direction to run into the cut or diameter of the shaft D than is the case when placed at *a*.

Cutting tools used in a planer are subject to the same conditions, as represented in Fig. 14. *a* is the fulcrum from which the tool springs, C is the work to be cut, and the dotted line B represents the direction in which the point of the tool springs into the work, thus increasing the cut according to the amount of spring, as in the case of a lathe too. This may be obviated, in a planer tool,

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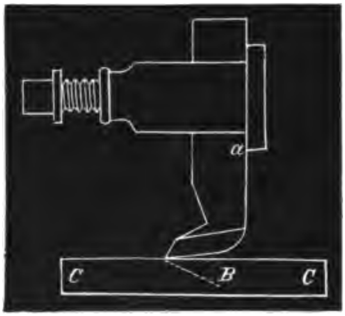
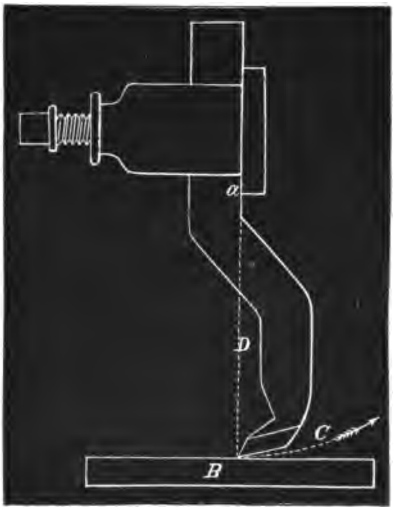
by bending its body, as shown in Fig. 15; *a* is the fulcrum off which the tool takes its spring; B is the work to be

Fig. 14.



cut; and the dotted line C is the line in which the point of the tool would spring (being in the direction denoted by the arrow), which is not in this case into the cut, but

Fig. 15.



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rather away from it, in consequence of the point of the tool standing back from a line perpendicular to the line of the back part of the tool, as shown by the dotted line D.

Tools that are necessarily slight in form, especially those for use in a planer, are more subservient to the evil effects of spring than those of stouter body; and in light planers, when the tool springs in, the table will sometimes lift up, and the machine become locked, the cut being too deep for the belt to drive. The tool most subservient to spring is the parting or grooving tool shown in Fig. 16, which,

Fig. 16.

having a square nose and a broad cutting surface placed parallel to the travel of the cut, and requiring at times to be slight in body, combines all the elements which predispose a tool to spring, to obviate which, it should be placed at or a little below the centre, if used in a lathe under disadvantageous conditions, and bent similarly to the tool shown in Fig. 15, if for use in a planer, unless under favorable conditions.

The point is made thicker to give clearance to the sides, so that it will only cut at the end, and the breadth is left wider than other parts to compensate in some measure for the lack of substance in the thickness.

For use on wrought-iron or steel, when the tool is very thin, or when it requires to enter the metal to an unusual depth, or requires to stand far out from the tool post, the tool should be made as shown in Fig. 17, which will obviate the necessity of bending the body of the tool, and prevent it from the digging in and breaking off so common under those conditions. When used upon wrought-

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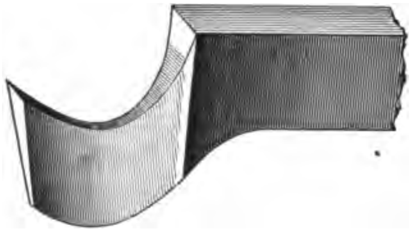
iron or steel, the cutting point should be supplied freely with oil.

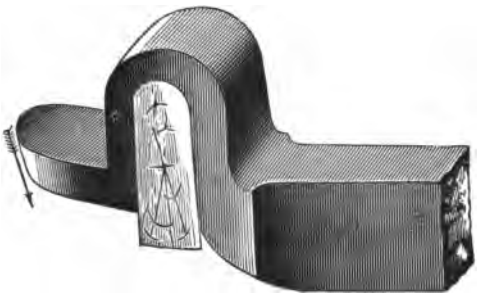
The spring tool, shown in Fig. 18, is especially adapted to finishing sweeps curves, and round or hollow corners, and may be used with equal advantage on any kind of

Fig. 17.



metal whatever, performing its duty more perfectly than any other form of tool could, since the conditions under which it operates, that is, a very broad cutting surface, would cause any other tool to dig into the work. The spring tool, however will spring rather away from than

Fig. 18.



into its cut, the only objection to its use being that in consequence of this qualification it is apt to spring into the softer and away from the harder parts of the metal. Its capability, however, to take a broad surface of cut,

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when the cutting edge stands a great way out from the tool post, renders its use for some work imperative as a finishing tool, while under ordinary conditions it will perform its duty sufficiently accurately for all practical purposes. As illustrated, its top face has a little rake to fit it for use on wrought-iron; for use on brass and cast-iron the top face should have negative top rake. In cases where the conditions render it liable to spring, the horizontal level of the top face may be made even with the bottom face of the body of the tool, or the body of the tool may be bent for the reasons explained by Figs. 13, 14, and 15, and the accompanying explanations.

The top face of a spring tool should be filed up very smoothly before being hardened, and it should never be ground upon that face. The bevel in the direction of the arrow should be less for cast-iron and brass than for other metals, but should in no case be excessive, whatever the inclination of the top face may be. The bend of the tool should be left soft, the cutting face being hardened to a straw-color for stout tools, and a brown for slight ones. The face denoted by the arrow should, after grinding, be smoothed with an oilstone. For use on steel and wrought-iron, it should be freely supplied with either soapy or other water; and for finishing cast-iron, such water may also be used; and that metal will cut as clean and as polished as wrought-iron, providing the speed at which it is cut is a *very slow one.* When this tool is to be used a very long way out from the tool post, the wooden wedge, shown driven in the bend, should be taken out.

SIDE TOOLS FOR IRON.

Side tools for iron are subject to all the principles already explained as governing the shapes of front tools, and differ from them only in the fact that the cutting end of the tool is bent around to enable the cutting edge on one side to cut a face on the work which stands at right angles

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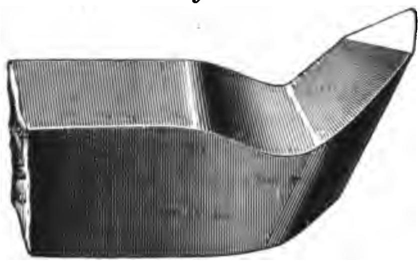
with the straight cut. A front tool is used to take the straight cut nearly up to the shoulder; then a side tool is introduced to take out the corner and cut the side face.

Fig. 19.



A side tool, whose cutting end is bent to the left, as in Fig. 19, is called a left-handed side tool; and one which is bent to the right, a right-handed side tool. The cutting edges should form an acute angle, so that, when the point of the tool is cutting out a corner, either the point only or one edge is cutting at a time; for if both of the edges cut at once, the strain upon the tool causes it to spring in.

For heavy work it may be made more round-nosed, and allowed to cut all round the curve, and with a coarse feed. It is also an excellent tool for roughing out sweeps or curves; and for use on small short bolts, it may be used on the parallel part as well as under the head.

For taking out a corner or fillet in slight work, which is liable to spring from the pressure of the cut—the point must be rounded very little, and the fillet be shaped by operating the straight and cross feed of the lathe. It is made right or left-handed by bending it in the required direction, that shown being a left-handed one.

The form of side tool shown in Fig. 19 is that most desirable for all small work where it can be got in; and in the event of a side face being very hard, it possesses the advantage that the point of the tool may be made to enter

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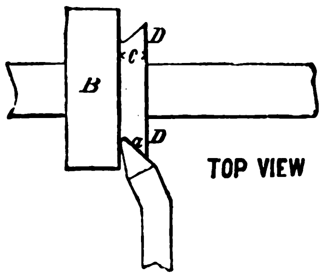
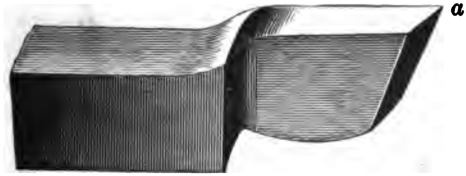
the cut first, and, cutting beneath the hard skin, fracture it off without cutting it, the pressure of the shaving on the tool keeping the latter to its cut, as shown in Fig. 20.

Fig. 20.



a is the cutting part of the tool; B is a shaft with a collar on it; *c* is the side cut being taken off the collar, and D is the face, supposed to be hard. The cut is here shown as being commenced from the largest diameter of the collar, and being fed inwards so that the point of the tool may cut well beneath the hard face D, and so that the pressure of the cut on the tool may keep it to its cut, as already explained; but the tool will cut equally as advantageously if the cut is commenced at the smallest diameter of the collar and fed outwards, if the skin, D, is not unusually hard.

Fig. 21.



For cutting down side faces where there is but little room for the tool to pass, the tool shown in Fig. 21 is used, *a* being the cutting edge. Not much clearance is

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required on the side face of this tool, the keenness being given to it by grinding the top face to a keener angle. This tool should be so placed that the point *a* cuts a shade the deepest. In forging it the hammering edgewise should be performed first, nor should any hammering be done to it edgewise after the steel has lost its redness. It should, for light duty and finishing purposes, only be tempered to a light straw color; but if it is made stout for heavy duty, it should be made as hard as fire and water will make it.

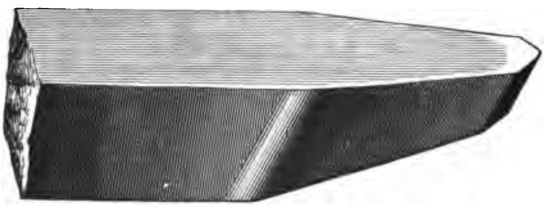
The spring of this tool does not affect it to any degree, since it springs vertically and in a line with the face of the cut, and not laterally and into it.

It is generally applied to chamfer off corners, such as those on the heads of hexagon bolt heads, and when the bolts are so short that the tool cannot be placed at sufficient angle in the tool post without being struck by the revolving driver or dog, the cutting end is bent round, from the shoulder, to an angle of about 45 degrees; any ordinary variation of angle being accommodated by altering the position of the tool in the tool post or clamp.

FRONT TOOL FOR BRASS WORK.

Fig. 22.

The main distinction between tools for use on iron or steel, and those for use on brass work, is, that the latter



do not require any top rake (unless the brass contains an unusually large proportion of copper). Fig. 22 presents a front tool for brass, which is a complete master tool,

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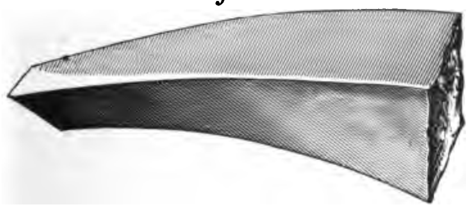
filling every qualification for all plain outside work, both for roughing out and finishing. For very light work, or when the tool must be held far out from the tool post, it may be given a little more rake on the bottom or side faces; while for finishing, the point may be more rounded and used with a coarser feed, providing the tool is rigid and not liable to spring. When held far out from the tool post, the side faces may be ground keener, and the top face have negative top rake—that is to say, some of the rake may be ground off the top face, and more given to the bottom or side faces; under such conditions, also, the cutting surface on the point of the tool may be reduced as small as convenient, so as to avoid the liability to spring. Ground round-nosed and smoothed with an oilstone, this tool gives a true and excellent finish to plain work.

SIDE TOOL FOR BRASS WORK.

The best side tool for brass is that shown in Fig. 23. It requires little or no top rake, and but little side or bottom rake, unless used upon very slight work, or used

Fig. 23.



under conditions rendering it liable to spring. For taking out corners, and for turning out recesses which do not pass entirely through the metal, it has no equal. When it is held far out from the tool-post, it should have the top face bevelled off, at an angle of which the cutting part is the lowest, which will thus prevent it from jarring or chattering, and from springing into the work. In grind-

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ing it, only the end should be ground, so that the curve of the side of the tool—which is intended to allow the body of the tool to clear the shoulder or flange of the work—shall be preserved.

It will take a parallel cut, provided the corner is slightly rounded, as easily and well as a side cut; and for small work, can be used to advantage for both purposes.

It is a far better tool than those bent around at the end after the manner of a boring tool, being easier to forge, easier to grind, and not so liable to either spring, jar, or chatter.

If a tool for use on brass be made too keen, it will give the surface of the brass a mottled appearance, the color appearing lighter in patches. Furthermore, the face of the cut will appear jarred or chattered, and the cutting must be performed at a slower speed and feed.

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CHAPTER II.

CUTTING SPEED AND FEED.

THE term "cutting speed," as applied to machine tools, means the number of feet of cutting performed by the tool edge, in a given time, or what is the same thing, the number of feet the shaving, cut by the tool in a given time, would measure if extended in a straight line. The term "feed," as applied to a machine tool, means the thickness of the cut or shaving taken by the tool.

Planing machines being constructed so that their tables run at a given and unchangeable speed, their cutting speed is fixed; and the operator has only, therefore, to consider the question of the amount of feed to be given to the tool at a cut, which may be placed at a maximum by keeping the tool as stout as possible in proportion to its work, making it as hard as its strength will allow, and fastening it so that its cutting edge will be as close to the tool post as circumstances will permit. In all cases, however, cast-iron may be cut in a planer with a coarser feed than is possible with wrought-iron. Milling machines should have their cutters revolve so that the cutting speed of the largest diameter of the cutter does not exceed 18 feet per minute, at which speed the cut taken may be made, without injury to the cutter, as deep as the machine will drive.

It is only when we treat of lathe work that the questions of feed and speed assume their real importance, for there is no part of the turner's art in which so great a variation of practice exists or is possible, no part of his art so intricate and deceptive, and none requiring so much judgment, perception, and watchfulness, not only because the nature of

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the work to be performed may render peculiar conditions of speed and feed necessary, but also because a tool may appear to the unpractised or even to the experienced eye, to be doing excellent duty, when it is really falling far short of the duty it is capable of performing. For all work which is so slight as to be very liable to spring from the force of the cut, for work to perform which a tool slight in body must be used, and in cases where the tool has to take out a sweep or round a corner which has a break in it, a light or fine feed must be employed; and it is therefore advisable to let the cutting speed be as fast as the tool will stand. But under all ordinary circumstances, a maximum of tool feed rather than of lathe speed will perform the greatest quantity of work in a given time. A keen tool, used with a quick speed and fine feed, will cut off a thin shaving with a rapidity very pleasing to the eye, but equally as deceptive to the judgment; for under such a high rate of cutting speed, the tool will not stand either a deep cut or a coarse feed; and the increase in the depth of cut and in the feed of the tool, obtainable by the employment of a slower lathe speed, more than compensates for the reduction of lathe speed necessary to their attainment, as the following remarks will disclose.

Wrought-iron, of about two inches in diameter, is not uncommonly turned with a tool feed of one inch of tool travel to 40 revolutions of the lathe. With a tool feed as fine as this, it is possible, on work of this size, to employ a cutting speed as high as 27 feet per minute, providing the depth of the cut does not exceed one-eighth of an inch, reducing the diameter of the work to $1\frac{3}{4}$ inches. The length of shaft or rod turned under such circumstances will be $1\frac{9}{32}$ inches per minute, since the lathe speed (necessary to give the tool a cutting speed of 27 feet per minute) would require to be about 51 revolutions per minute; and as each revolution of the lathe moves the tool forward $\frac{1}{40}$ of an inch, the duty performed is $\frac{51}{40}$ of an inch, or $1\frac{9}{32}$

inches of shaft turned per minute, as before stated. If, however, we turn the same rod or shaft of two inch iron, with a lathe speed of 36 revolutions per minute, and a tool travel of one inch to 24 revolutions of the lathe, the amount of duty performed will be $\frac{36}{24}$ inches, or $1\frac{1}{2}$ inches of shaft turned per minute. Here, then, we have a gain of about 17 per cent. in favor of the employment of the slow speed and quick feed. Nor is this all, for we have reduced the cutting speed to 19 feet, instead of 27 feet per minute, and the tool will, in consequence, stand the cut much longer and cut cleaner.

Pursuing our investigations still further, we find from actual test that, cutting at the rate of 27 feet per minute, the tool will not stand a cut deeper than one-eighth of an inch; whereas under the cutting speed of 19 feet per minute, it will take a cut of one-quarter of an inch in depth, thus considerably more than doubling the duty performed by the tool, in consequence of the decreased cutting speed and increased feed or tool travel.

Lathe work of about three-quarters of an inch in diameter may, if there is no break in the cut, be turned at a cutting speed of as much as 36 feet per minute, the feed being one inch of tool travel to about 25 revolutions of the lathe. The revolutions per minute of the lathe, necessary to give such a rate of cutting speed, will be about 183; the duty performed will therefore be $\frac{183}{25}$, or $7\frac{5}{16}$ inches of three-quarter inch iron turned per minute. A feed of one inch of tool travel to 25 revolutions of the lathe is greater than is generally employed upon work of so small a diameter as three-quarter inch, but is not too great for the generality of work of such a size; for the tool will stand either a roughing or smoothing cut at that speed, unless in the exceptional case of the work being so long as to cause it to spring away from the tool. Under these circumstances the feed may be reduced to one inch of tool travel to 30 or 40 revolutions of the lathe, according to the length and depth of the cut.

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It will be observed that the cutting speed given, for work of three-quarter inch diameter, is nearly double that given as the most advantageous for work of two inches diameter, while the feed or tool travel is nearly the same in both cases; the reason of this is that the tool can be ground much keener for the smaller sized than it could be for the larger sized work, and, furthermore, because the metal, being cut off the smaller work, is not so well supported by the metal behind it as is the metal being cut off the larger work, and, in consequence, places less strain upon the tool point, as illustrated in Figs. 24 and 25.

Fig. 24.

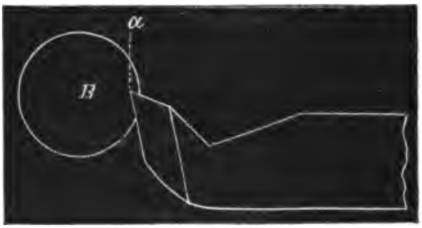
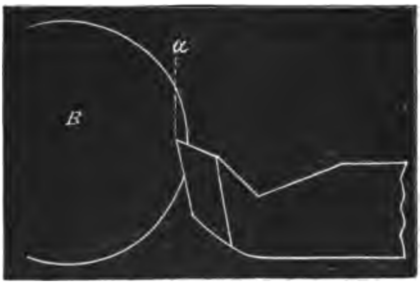


Fig. 25.



B is a shaft, and C is the tool in both cases. The dotted line *a*, in Fig. 24, does not, it will be observed, pass through so much of the metal of the shaft B, as does the dotted line *a*, of the shaft B, in Fig. 25. The metal in contact with the

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point of the tool in Fig. 24, is not, therefore, so well supported by the metal behind it as is the metal in contact with the point of the tool in Fig. 25, the result being that the tool, taking a cut on the smaller shaft equal in depth to that taken by the tool on the larger one, may have a higher rate of cutting speed without sustaining any more force from the cut, the difference in the resistance of the metal to the tools being equalized by the increased speed of the smaller shaft.

These conditions are reversed in the case of boring, the metal, being cut in a small hole, being better supported by the metal behind it than is the case in a larger hole or bore. This may be overcome by making the boring tool point cut below the horizontal centre of the work, while the body of the tool may, to keep it stout enough, be kept in the centre of the hole. But in a large bore, the effect is not so seriously encountered, because of the nearer approach of the circle to the straight line.

On heavy work it is specially desirable to have the tool stand a long time without being taken out to grind, for the following reasons: 1. It takes longer to stop and start the lathe, and to take out and replace the tool. 2. It takes longer to readjust the tool to its cut. 3. It takes more time to put the feed motion into gear again. 4. The feed motion is very slow to travel the tool up and into its cut, and to take up its play or lost motion. 5. Lastly, the tool should take a great many more feet of cut, at one grinding, than is the case with a tool for small work.

A tool used on work 5 inches diameter (the lathe making 20 revolutions to feed the tool one inch) would perform 314 feet of cutting in travelling a foot, the lathe having, of course, performed 240 revolutions; while one used on work 10 feet in diameter (with the same ratio of speed) will have performed 314 feet of cutting when the tool has travelled half an inch, and the lathe made 10 revolutions only. In practice, however, the feed for larger work is increased

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in a far greater ratio than the cutting speed is diminished, as compared with small work; but in all cases the old axiom and poetical couplet holds good, that

"A quick feed
And slow speed"

are the most expeditious for cutting off a quantity of metal, and in the case of cast-iron, for finishing it also.

A positive or constant rate of cutting speed for large work cannot be given, because the hardness of the metal, the liability of the work to spring in consequence of its shape, the distance of the point of the tool from the tool post, and other causes already explained, may render a deviation necessary, but the following are the approximate speeds and feeds for ordinary work:

TABLES OF CUTTING SPEEDS AND FEEDS.

Table for Steel.

Diameter of work in inches.	ROUGHING CUTS. Speed in feet per minute.	ROUGHING CUTS. Feed.	FINISHING CUTS. Speed in feet per minute.	FINISHING CUTS. Feed.
1 and less	20	25	20	30
1 to 2	18	25	18	30
2 to 3	18	25	15	30
3 to 6	15	20	15	30

For Wrought-Iron.

Diameter of work in inches.	ROUGHING CUTS. Speed in feet per minute.	ROUGHING CUTS. Feed.	FINISHING CUTS. Speed in feet per minute.	FINISHING CUTS. Feed.
1 and less	35	25	38	30
1 to 2	25	20	30	30
2 to 4	25	20	25	25
4 to 6	23	20	23	25
6 to 12	20	15	23	20
12 to 20	18	12	18	16

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For Cast-Iron.

Diameter of work in inches.	ROUGHING CUTS.		FINISHING CUTS.	
	Speed in feet per minute.	Feed.	Speed in feet per minute.	Feed.
1 and less	38	20	38	20
1 to 2	35	20	35	16
2 to 4	30	20	30	10
4 to 6	25	16	25	6
6 to 12	20	14	20	6
12 to 20	20	10	20	4

For Brass.

Diameter of work in inches.	ROUGHING CUTS.		FINISHING CUTS.	
	Speed in feet per minute.	Feed.	Speed in feet per minute.	Feed.
1 and less	120	25	120	25
1 to 2	100	25	100	25
2 to 4	80	25	100	25
4 to 6	70	25	70	25
6 to 12	60	25	70	25

For Copper.

Diameter of work in inches.	ROUGHING CUTS.		FINISHING CUTS.	
	Speed in feet per minute.	Feed.	Speed in feet per minute.	Feed.
1 and less	350	25	400	25
2 to 5	250	25	300	25
5 to 12	200	25	200	25
12 to 20	150	25	150	30

In cases where the cuts are unusually long ones, the cutting speeds may be slightly reduced except in the case of copper. All the tools we have so far described may justly be termed master tools, for work on external surfaces, each entirely filling its arena, and all other tools used on outside work are simply modifications called into requisition to suit exceptional cases.

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CHAPTER III.

BORING TOOLS FOR LATHE WORK.

STANDARD bits and reamers have superseded the use of boring tools for all special and many other purposes, but there are numerous cases where a boring tool cannot be dispensed with, especially in repairing shops and for promiscuous work.

Boring tools for use on lathe work require to be shaped with greater exactitude than any other lathe tools, for the reason that they are slighter in body in proportion to the duty required of them than any other; and as a rule, the cutting edges standing further out from the tool post or clamp, the body of the tool is more subject to spring from the strain of the cut. It is obvious that, if the hole to be bored out is a long one, the cutting edge of the tool will become dull at the end of the hole as compared to what it was at the commencement (a remark which, of course, applies to all tools); but in tools stout in proportion to the duty required of them, and held close in to the tool post, the effect of the slight wear of the cutting edge, due to a finishing cut, is not practically appreciable. In the case of a boring tool, however, the distance of the cutting edge from the tool post renders the slightest variation in the cutting capability of the tool sufficient to affect the work, as may be experienced by boring out a hole half of its length, and then merely exerting a pressure on the body of the tool, as near the entrance of the hole as possible, with the fingers, when the size of the last half of the hole will be found to have varied according to the direction in

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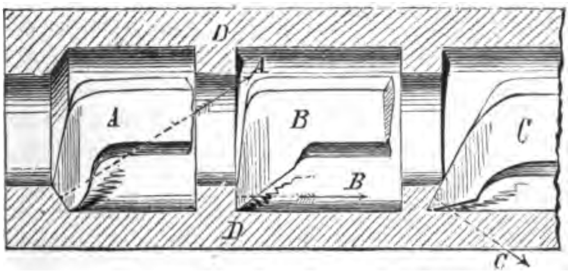
which the pressure was placed. As a result of this extreme sensitiveness to spring, the tool is apt to spring away from the cut as the boring proceeds, thus leaving the hole smaller at the back than at the front end. To remedy this defect, several very fine finishing cuts may be taken; but a better plan is to so shape the tool that its spring will be in a direction the least liable to affect the size of the bore of the work.

The pressure on the cutting edge of a tool acts in two directions, the one vertical, the other lateral. The downward pressure remains, under equal conditions, at all times the same; the lateral pressure varies according to the direc-

Fig. 26.



tion of the plane of the cutting edge of the tool to the line or direction in which the tool travels: the general direction of the pressure being at a right angle to the general direction of the plane of the cutting edge. For example, the lateral pressure, and hence the spring of the various tools, shown in Fig. 26, will be in each case in the direction denoted by the dotted lines. D is a section of a piece of metal requiring the three inside collars to be cut out; A, B, and C are variously shaped boring tools, from which it will be seen that A would leave the cut in proportion as it suffered from spring, which would increase as the tool edge became dull, and that the cut forms a wedge, tending to force the tool towards the centre of the work. B would neither spring

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into nor away from the cut, but would simply require more power to feed it as the edge became dulled; while C would have a tendency to run into the cut in proportion as it springs; and as the tool edge became dull, it would force the tool point deeper and deeper into the cut until something gave way. Now, in addition to this consideration of spring, we have the relative keenness of the tools, it being obvious at a glance that (independent of any top rake or lip) C is the keenest, and A the least keen tool; and since wrought-iron requires the keenest, cast-iron a medium, and brass the least keen tool, it follows that we may accept, as a rule, C for wrought-iron, B for cast-iron, and A for brass work. To this rule there are, however, variations to be made to suit exceptional cases, such for instance as when a hole terminates in solid metal and has a flat bottom, in which case the tool B (slightly modified towards the form of tool C) must be employed. Or suppose a hole in cast-iron to be, as is often the case, very hard at and near the surface of the metal. Tool A would commence cutting the hard surface, and, becoming dull, would spring away from the cut in spite of all that could be done to prevent it; while tool B would commence to cut both the hard and the soft metal together, the cutting edge wearing rapidly away where it came into contact with the hard surface of the metal; and these conditions would, in both cases, continue during the whole operation of boring, rendering it difficult and tardy. But if the tool C were employed, the point of the tool would commence cutting the soft part of the metal first, and would undermine the hard surface, and (from the pressure) break it instead of cutting it away, as shown in Fig. 27, in which *a* is the point of the tool, and from *a* to B is the cutting edge; the dotted lines, *c* and D, represent the depth of the cut, *c* being the inside skin of the metal, supposed to be hard.

The angle at which the cutting edge stands to the cut causes the pressure, due to the bending and fracturing of

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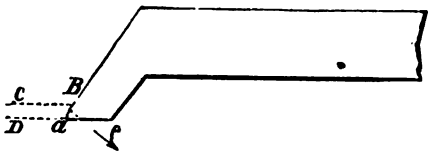
the shaving, to be in the direction of *e*, which keeps the tool point into its cut; while the resistance of the tool point to this force, reacting upon the cut, from *a* to B, causes the hard skin to break away.

Fig. 27.



When a cut is being taken which is not sufficient to clean up or true the work, less top rake must be given, as a very keen tool loses its edge more quickly than one less keen. The reason for taking the rake off the top of a tool is that, if it were taken off the bottom, the cutting edge would not be so well supported by the metal, and would have a tendency to scrape, which rule applies both to inside and outside cuts. For brass work, top rake is never applied, because it would cause the tool to jar and cut roughly, bottom rake alone being sufficient to give a tool for brass the requisite keenness.

The application of top rake or lip to a boring tool lessens the strain due to serving the metal; by presenting a keener cutting edge, it lessens the tendency to lateral spring, and increases that to vertical spring, and is beneficial in all cases in which it can be employed. Upon wrought-iron and steel it is indispensable; upon cast it may be employed to a limited degree; and upon brass it is inadmissible by reason of its causing the tool to either jar or chatter. In Fig. 28, B represents a section of the work, No. 1 represents a boring tool with top rake, for wrought-iron, and No. 2 a tool without top rake, for brass work, which may be also used for cast-iron when the tool stands a long way out from the tool post or clamp, under which circumstances it is

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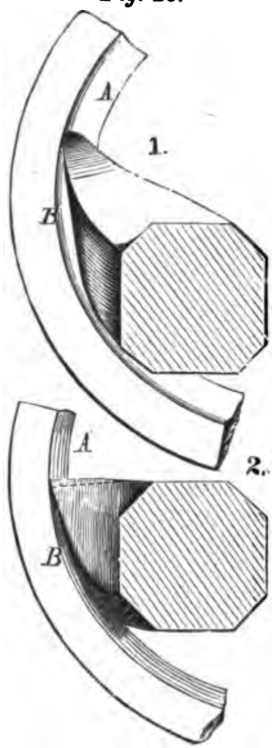
liable to jar or chatter. A tool for use on wrought-iron should have the same amount of top rake, no matter how far it stands out from the tool post; whereas one for use on cast-iron or brass requires to be the less keen the further it stands out from the tool post. To take a very smooth cut on brass work, the top face of the tool, shown at 2 in Fig. 28, must be ground off, as denoted by the dotted line.

Fig. 28.



We have now to consider the most desirable shape for the corner of the cutting edge. A positively sharp corner, unless for a special purpose, is very undesirable, because the extreme point soon wears away, leaving the cutting qualification of the tool almost destroyed, and because it leaves the work rough, and can only be employed with a very fine feed. It may be accepted as a general rule that, for roughing cuts, on brass work, the corner should be sufficiently rounded to give strength to the tool point; while, in finishing cuts, the point may be made as round as possible without causing the tool to jar or chatter. Now, since the tendency of the tool to jar or chatter upon all metals depends upon four points, namely, the distance it stands out from the tool post, the amount of top rake, the acuteness or keenness of the general outline of the tool, and the shape of the cutting corner, it will readily be perceived that considerable judgment is required to determine the most desirable form for

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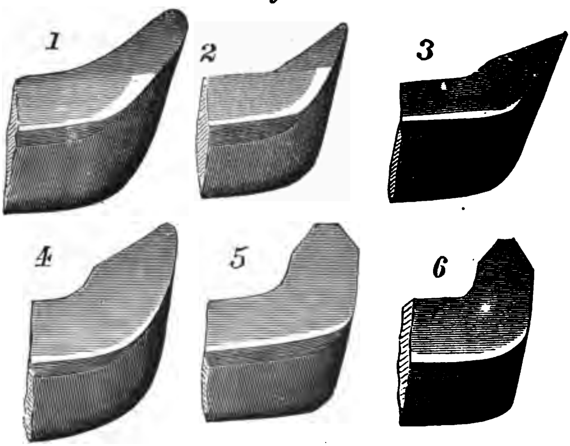
any particular conditions, and that it is only by understanding the principles governing the conditions that a tool to suit them may be at once formed.

In Fig. 29 will be found the various forms of boring tools for ordinary use. No. 1 is for use when the conditions admit of a heavy cut on wrought-iron. No. 2 is for use on wrought-iron when the tool stands so far from the tool post as to be necessarily subject to spring. No. 3 is to cut out a square corner at the bottom of a hole in wrought-iron. No. 4 is for taking out a heavy cut in cast-iron. No. 5 is

Fig. 29.



for taking out a finishing cut in cast-iron when the tool is proportionally stout, and hence not liable to spring or chatter: the point being flat, the cutting being performed by the front corner, and the back part being adjusted to merely scrape. No. 6 is for use on cast-iron under conditions in which the tool is liable to jar or spring.

An inspection of all these tools will disclose that the tool point is more rounded for favorable conditions, that is, when the body of the tool is stout, and the cutting edge is not held far out from the tool post; that, to prevent jarring, the

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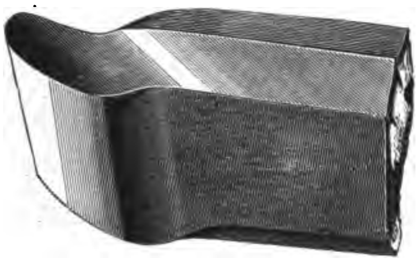
point of the tool is made less round, which is done to reduce the cutting surface of the tool edge (since it is apparent that, with a given depth of cut, the round-pointed tool will present the most cutting edge to the cut); and that, to further prevent jarring or chattering, the leading part of the cutting edge is ground at an angle; while, as another precaution against that evil, the general form of the tool is varied from that of tool C, in Fig. 26, towards that of tool A in the same figure; while for brass work, no top rake or lip is employed, but the tool is bevelled off to suit those cases in which it is liable to excessive spring. It is obvious that the feed may be coarser for a round-nosed than for a more acute tool, and that, the rounder the nose, the smoother the cut will be with the same rate of feed.

For heavy duty on wrought-iron, whether in large or small holes, the boring tool, represented in Fig. 30, has no

Fig. 30.



equal. The rake on the top face makes the cutting edge perform its duty on the front edge, and the strain due to bending the shaving tends to draw the tool to its cut, giving it an inclination to feed itself forward, thus relieving the feed screw of a part of the duty due to the strain of feeding.

The cutting edge should not stand above the horizontal level of the top of the tool body; otherwise, so stout a tool could not be gotten into a given size of hole; a consideration which, in small holes, is of the utmost importance. For

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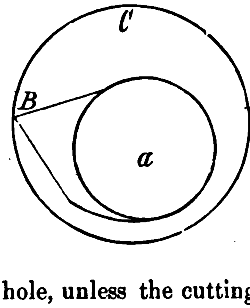
similar duty on brass, the tool shown in Fig. 31 is the best that can be employed.

Fig. 31.

BORING TOOL FOR BRASS.

When, upon brass work, a boring tool has a broad cutting surface, such as is required to cut a recess, the only way to prevent extreme chattering and jarring is to grind off the top face, giving it negative top rake, as shown in Fig. 32: *a* being a section of the body of the tool, B the cutting part, and *c* the outline of the hole. B, being the lowest point of the top face, possesses negative top rake, and a corresponding tendency to scrape rather than cut keenly. The point B should always be above the centre of the hole, so that, in springing, it will spring away from and not into its cut. A boring tool, slight in proportion to its duty, and for use upon small wrought-iron work, should always be placed so that its cutting edge is a little below the centre of the hole, in which case the bottom of the body of the tool is liable, in small holes, to bear against the bottom of the hole, unless the cutting part is made to be a little below the centre of the body of the tool, rendering it rather difficult to grind on the top face. It is not, however, imperatively necessary to grind it there, since it can be sharpened by grinding the side faces;

Fig. 32.



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and the advantage gained by being enabled to get, into a given sized hole, a stouter tool than otherwise could be done, and, as a result, to take deeper and more nearly parallel cuts (for such tools generally spring off their cut at the back end of the hole, leaving it taper unless several light cuts are taken out), more than compensates for the extra wear of the tool, consequent upon being able to grind it upon one part only.

Boring tools for use on wrought-iron, cast-iron, steel or copper, require very little side or bottom rake, only sufficient, in fact, to well clear the sides of the cut, and the straighter these side faces are kept the stronger the tool; and the better the cutting edges are supported by the metal behind them, the longer will they stand without regrinding.

When boring light brass work, it is well to hold a brush near the entrance of the hole, to prevent the turnings from flying about the shop; while cutting tools for outside brass work may have a split-leather washer forced over the body near the cutting end for the same purpose.

After a piece of brass or cast-iron work has been bored and taken out of the lathe, and is found on trial to fit a little too tight, it may, if it is difficult to chuck it true again, be eased by a half-round scraper, as follows: Take an old half-round, smooth file, and grind the teeth completely out of the flat face; then grind the edges to an angle sufficiently acute to cut freely, as a scraper; then rechuck the work in the lathe as nearly true as possible, and revolve it at such a speed that the scraper will cut at about 380 feet per minute; then apply the scraper edge to the bore of the hole at the bottom, moving it along the bore and holding it firmly. If the flat face and the bevelled edge of the scraper be ground true and even, and care is taken in using it to take out the metal only where required, this tool will perform excellent duty and cut very smoothly. It may also be used to advantage to ease out by hand the

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narrow places of a hole that is oval, or the small end of one that is taper and requires to be made parallel. The smoothness of its work is much improved by smoothing its edge upon an oilstone. Here it may be well to state that the application of an oilstone to the cutting edges of a boring tool increases its tendency to chatter; if, therefore, a hole requires to be made unusually smooth, the tool must be given less top rake and may then be oilstoned. In many cases a tool may be prevented from chattering by holding it with the fingers as near the entrance of the hole as possible.

BORING TOOL HOLDERS.

For use on holes too small to admit of a bar having a sliding head, which are usually bored with a slide rest tool, a boring tool holder may be employed to great advantage. Such a holder may be made by squaring or flattening one end of a round bar of iron so that it will fit into the tool post of the lathe, and cutting into the opposite end a groove to receive a short boring tool, the latter being fastened to its place by set screws provided in the holder or by being wedged in with a small wedge. Various sizes of such holders should be made, the larger sizes being provided with set screws to hold the tool. For use in holes of from two to eight inches bore, such an appliance is invaluable, especially if the hole to be bored is of unusual depth; because the bar may be made very stout in proportion to the size of the hole, and will, therefore, stand a depth of cut and a rate of feed totally impracticable with an ordinary boring tool, and will not spring away from its cut towards the back end of the hole, as boring tools are apt to do. Furthermore, the cutting tools, being small, are easily forged, ground up, and renewed when worn out; and the bar maintains its original length, which may be made to suit the depth of hole required to be bored; while a boring tool becomes shorter each time it requires reforging.

For truing out broad recesses in large work, the slot in

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the end may be made large enough to receive two tools, one to turn the inside and the other the outside of the recess.

For use upon holes of a very large bore, or upon outside work in which the tool requires to stand a long way out from the slide rest, as sometimes occurs when the diameter of the work is so near the full size, the lathe will swing; that there is not sufficient room for the slide rest of the lathe to pass under the work, a square tool holder should be employed, such tool holder being a stout bar of square iron, say 2½ inches square, and having a complete tool box on one end, the tool box being provided with two stout steel set screws.

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CHAPTER IV.

SCREW-CUTTING TOOLS.

LATHE tools for cutting screws have necessarily, from the nature of their duty, a comparatively broad cutting surface, rendering them very subject to spring. Those used for V threads, being ground to fit the V of the thread, are, in consequence, weak and liable to break; to avoid which they should only be given enough bottom rake to clear the thread well, and top rake sufficient to made them cut clean. They are used at a slow rate of cutting speed, and may therefore be lowered to a straw-colored temper (as reducing the temper strengthens a tool). Firmness and strength are of great importance to this class of tool, so that it should be fastened with the cutting edge as near to the tool post as is convenient.

For use on wrought-iron, the V or thread-cutting tool is sometimes given side rake; but this is not a necessity and is of doubtful utility, because the advantage gained by its tendency to assist in feeding itself is quite counterbalanced by its increased liability to break at the point. It should always be placed to cut at the centre of the work.

If the pitch of the screw to be cut is very coarse, a tool nearly one-half of the width of the space between one thread and the next should be employed, so as to avoid the spring which a tool of the full width would undergo. After taking several cuts, the tool must be moved laterally to the amount of its width, and cuts taken off as before until the tool has cut somewhat deeper than it did before

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being moved, when it must be placed back again in its first position, and the process repeated until the required depth of thread is attained.

Fig. 33.

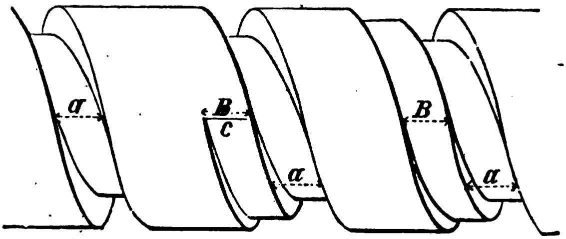

Fig. 33 represents a thread or screw during the above described process of cutting. *a a a* is the groove or space taken out by the cuts before the tool was moved; B B represents the first cut taken after it was moved; *c* is the point to which the cut B is supposed (for the purpose of this illustration) to have travelled.

The tool used having been a little less than one-half the proper width of the space of the thread, it becomes evident that the thread will be left with rather more than its proper thickness, which is done to allow finishing cuts to be taken upon its sides, for which purpose the side tool (given in Fig. 21) is brought into requisition, care being taken that it be placed true, so as to cut both sides of the thread of an equal angle to the centre line of the screw.

In cutting V threads of a coarse pitch, the tool may be made less in width than the required space between the threads demands, so that it may be moved a little laterally in order to take a cut off one side of the thread only at a time, by which means a heavier cut may be taken with less liability for the tool to spring in; but the finishing cut is better if taken by a tool of the full width or shape of the thread.

The most accurate method of cutting small V threads

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is to use a stout chaser fastened in the tool post, and then feed it with the screw-cutting gear of the lathe, the same as with a common screw-cutting tool. Such a chaser should be made hollow in the length of the tooth, possess a minimum of top rake, and be placed to cut at the centre of the work; and it should be so placed in the tool post that the teeth stand exactly parallel to the line of the cut.

Fig. 34.

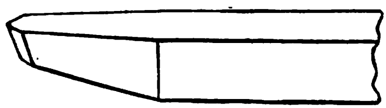


Fig. 34 represents a tool for cutting an outside V thread in brass work. When, however, the tool point must, of necessity, stand far out from the tool post, it must be given negative top rake, to make it cut smoothly and prevent its jarring. To adapt this tool to cutting V threads on iron, it is only necessary to give it top rake.

Fig. 35.

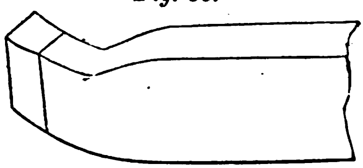
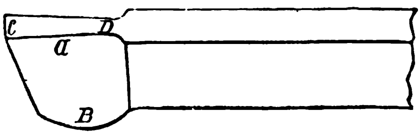


Fig. 35 represents a very stout tool, adapted to cutting coarse square threads on wrought-iron or steel. For cutting square threads on brass work, the tool shown in Fig. 36 should be used.

Fig. 36.



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In cutting V threads upon either inside or outside work, great care should be taken to grind the V tool to the exact proper angle, and to also set it quite true in the lathe; to accomplish both of which results, we have the gauge shown in Fig. 37, and supplied by H. S. Manning & Co.

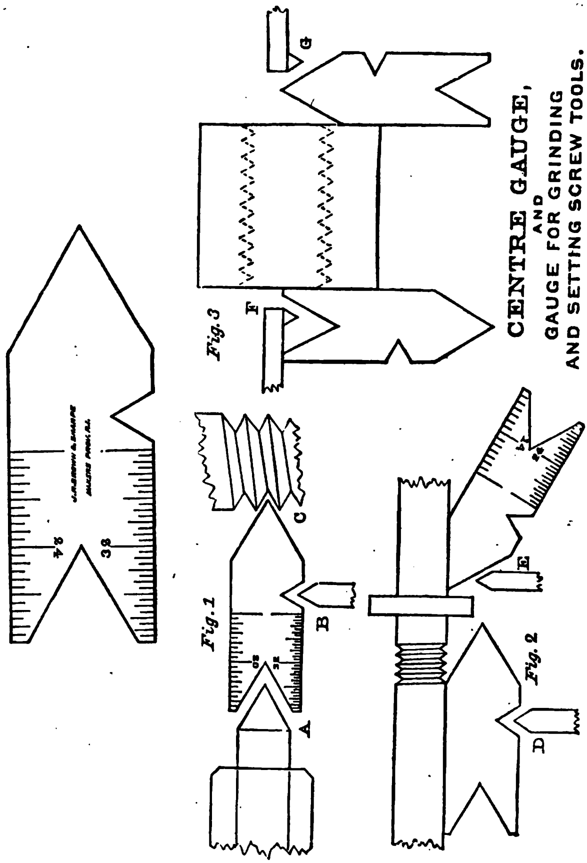

Fig. 37.

The above cuts show the various uses to which this gauge can be applied.

In Fig. 1, at A, is shown the manner of gauging the

angle to which a lathe centre should be turned; at B, the angle to which a screw-thread cutting tool should be ground, and at C, the correctness of the angle of a screw-thread already cut.

In Fig. 2, the shaft with a screw-thread is supposed to be held on the centre of a lathe. By applying the gauge as shown at D, or E, the thread tool can be set at right angles to the shaft, and then fastened in place by the screw in tool post, thereby avoiding imperfect or leaning threads.

In Fig. 3, the manner of setting the tool for cutting inside threads is illustrated. The angles used in this gauge are sixty degrees. The four divisions upon the gauge of 14, 20, 24 and 32 parts to the inch are very useful in measuring the number of threads to the inch of taps and screws.

The following parts to the inch can be determined by them—namely, 2, 3, 4, 5, 6, 7, 8, 10, 14, 16, 20, 24 and 32.

If the tool is not ground to the correct V, or is not set true in the lathe, the result is, that the threads will bear upon each other upon one side, or a portion of one side only—thus reducing the amount of wearing surface, and causing the threads to soon become a loose fit, as well as to be weaker than they should be. A V thread cut by a V tool in the lathe is not so strong as one cut by a chaser, because chasers cut a thread slightly rounded at the top and bottom; whereas the V tool leaves a sharp corner.

At the termination of the thread, it is necessary to cut a recess as deep as the thread, in order to give the chaser clearance, and prevent it from ripping into the shoulder, which would form the termination of the thread in the absence of a recess. It is a very common practice to cut this groove or recess with a V tool or graver point, instead of with a round-nosed tool, thus producing a recess having

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a conical instead of a curved outline: the result being to very seriously impair the strength of the bolt, and cause it, under severe strains, to fracture across the section of the bottom of the groove.

In a series of experiments made a few years ago, by the English government, upon targets representing ships' armor, the bolts were found to be unable to withstand the shock caused by the cannon shot striking the target; and it being observed that the fracture nearly always occurred across the section above referred to, the clearance grooves were made with a hollow curve, which obviated the defect.

HAND CHASING.

To cut a screw by hand in the lathe, we proceed as follows: The work is turned up to the required size, and then on the outside of the work we employ the V tool shown in Fig. 38; which tool is made of a piece of steel

Fig. 38.

about $\frac{3}{16}$ or $\frac{1}{4}$ inch thick, and $\frac{5}{8}$ inch deep, the holding end being fitted into a handle. The point A is the cutting edge; the point B being formed so that when the tool is pressed firmly to the lathe-rest face, it will not slip but will hold fast; and the top face being given a little top rake when the tool is used upon wrought-iron or steel, whereas negative top rake is necessary for use upon brass work.

To start the thread, the lathe should be run at a fast speed; and the heel of the tool being pressed firmly to the

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face of the lathe-rest, the point of the V of the tool being brought firmly into contact with the work, while the handle of the tool must be twisted from right to left at the same time as it is moved bodily from the left to the right. It is the relative quickness with which these combined movements are performed which will determine the pitch of the thread. The results of these combined movements will be a fine groove cut upon the work, and of the same distance from one groove to the next as the distance of one tooth of the chaser to the next. If the spiral groove so cut is only the proper pitch at one part, as, say, at the starting end, the chaser may be so held and applied as only to touch that end, when it will readily find the groove if applied lightly to it. Then several light cuts may be taken off that end, before attempting to carry the thread along.

The chaser is applied by being pressed lightly against the work, and moved along the lathe-rest at as nearly the proper speed as can be judged. The chaser should be held so that its hind teeth press hardest against the work, which will keep them in the starting groove and act as a guide to the front teeth, while they extend the groove, carrying the thread forward to the required distance on the work.

The reason for running the lathe at a comparatively fast speed is, that the tool is then less likely to be checked in its movement by a seam or hard place in the metal of the bolt, and that, even if the metal is soft and uniform in its texture, it is easier to move the tool at a regular speed than it would be if the lathe ran comparatively slowly.

If the tool is moved irregularly or becomes checked in its forward movement, the thread will become "drunken," that is, it will not move forward at a uniform speed; and if the thread is drunken when it is started, the chaser will not only fail to rectify it, but, if the drunken part occurs in a part of the iron either harder or softer than the rest

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of the metal, the thread will become more drunken as the chaser proceeds. It is preferable, therefore, if the thread is not started truly, to try again, and, if there is not sufficient metal to permit of the starting groove first struck being turned out, to make another further along the bolt. It takes much time and patience to learn to strike the requisite pitch at the first trial; and it is therefore requisite for a beginner to leave the end of the work larger in diameter than the required finished size, so as to have metal sufficient to turn out the first few starting grooves, should they not be true or of the correct pitch. If, however, a correct starting groove is struck at the first attempt, the chaser may be applied sufficiently to cut the thread down to and along the body of the bolt; then the projection may be turned down with the graver to the required size, and the chasing proceeded with.

After the thread is struck, and before the chaser is applied to it, the top face of the rest should be lightly filed to remove any burrs which may have been made by the heel of the V tool or graver; or such burrs, by checking the even movement of the chaser, will cause it to make the thread drunken. Where the length of the thread terminates, a hollow curved groove should be cut, its depth being even with the bottom of the thread; the object of this groove is to give the chaser clearance, and to enable you to cut the thread parallel from end to end and not to leave the last thread or two larger in diameter than the rest. Another object is to prevent the front tooth of the chaser from ripping in and breaking off, as it would be very apt to do in the absence of the groove.

TO MAKE A CHASER.

Chasers are cut from a hub, that is to say, a cutter formed by cutting a thread upon a piece of round steel, and then forming cutting edges by cutting a series of grooves along the length of the hub. These grooves

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should be V-shaped, the cutting side of the groove having its face pointing radially towards the centre of the hub. Hubs should be tempered to a brown color. A chaser is made from a piece of flat steel whose width and thickness increases with the pitch of the thread ; the following proportions will, however, be found correct:

NUMBER OF THREADS PER INCH.	NUMBER OF TEETH IN THE CHASER.	THICKNESS OF THE CHASER.
24 to 20	12 to 14	$\frac{1}{4}$ inch.
18 to 14	10	$\frac{5}{16}$ "
12 to 8	9 to 6	$\frac{5}{16}$ "
6 to 4	7 to 6	$\frac{3}{8}$ "

The end face of the chaser should be filed level and at an angle with both the top face and the front edge of the steel, both top and bottom rounded off so that at the top it will not dig into the shoulder at the end of the thread, and at the bottom it will not strike against a burr or other obstruction or the face of the lathe rest, and thus be retarded in its forward movement while being cut. The hub is then driven in the lathe between the centres, the chaser being held in a handle sufficiently long to enable the operator to hold it with one hand, and press the shoulder against the end so as to force the end of the chaser against the hub, which will of itself carry the chaser along the rest. During the operation of cutting the chaser by the hub, the former will be upside down, its cutting face (when finished) being that which during this operation is resting on the face of the lathe-rest, which latter should be placed a short distance from, and not close up to the hub. After the chaser has passed once down the hub, special attention should be paid as to whether the front tooth will become a full one ; if not, the marks cut by the hub should be filed out again, and a new trial essayed. It must be borne in mind that, the chaser being held upside down, the back tooth, while cutting the chaser, becomes the front

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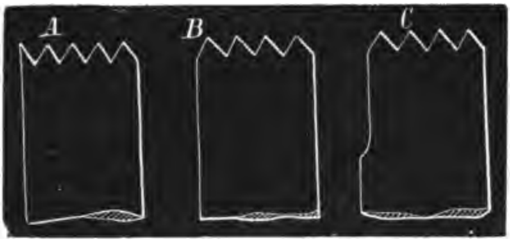
one when the chaser is reversed and ready for use. The hub should be run at a comparatively slow speed, and kept freely supplied with oil, it being an expensive tool to make, and this method of using preserves it. In Fig. 39, A is a chaser whose front tooth is not a full one; B is a chaser with a full front tooth; and C is of the same form as A, when it is, as far as possible, corrected.

Fig. 39.



The cutting operation of the hub upon the chaser is continued until the thread upon the latter is cut full, when it is taken to the vise and filed as follows:

The top and bottom edges immediately behind the front tooth are rounded off as already directed. Then along the bottom of the chaser the teeth are rounded off to prevent them from catching against any burr on the face of the lathe rest.

An outside chaser for cutting wrought-iron by hand should be made hollow in the length of the tooth, and have top rake, to enable it to cut easily; for the strain required to bend the shaving out of the straight line will hold the teeth to their cut. Top rake may, in fact, be applied to such an extent that the chaser will cut well of itself without having any force applied to it except sufficient to keep it level, but if made so keen, it soon loses its edge and is very apt to break.

For use on cast-iron or brass, an outside chaser must be

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made less keen by giving the top face of the teeth no rake, or else negative top rake and cutting the teeth less hollow in their lengths. The latter object is obtained by moving the handle, in which the chaser is fixed, up and down while the hub is cutting it.

The lathe rest should be so adjusted that the chaser teeth cut above the horizontal centre of the work. The teeth of the chaser should fit the thread on the bolt along all their length when the body of the chaser is horizontal, and then the least raising of the handle end of the chaser will present the teeth to the work in position to cut, while the teeth behind the cutting edge will fit the thread being cut, sufficiently close to form a guide to steady the chaser. This method of using will not only keep the thread true, but will preserve the cutting edge of the chaser. If a chaser has top rake, and the handle end is held too high and so that the back of the teeth are clear of the thread, it will cut a thread deeper than are its own teeth; if, on the other hand, the top face is beveled off, and the handle is held too high, it will cut a thread shallower than the chaser teeth.

Fig. 40 represents a chaser in use on wrought-iron. It will be observed that the tops of the teeth do not stand at a right angle to the side edges of the chaser; the object of this is to make the front edge of the chaser clear the driver or dog driving the work.

An inside chaser, that is, one for cutting threads in a hole or bore, should be, if to be used for cutting a right-handed thread, cut off a left-handed hub, otherwise the chaser will have its thread sloping in the opposite direction to the thread to be cut, as may be demonstrated by placing an inside and outside chaser (both having been cut off the same hub) together, when it will be seen that the teeth of one will not fit in the teeth of the other, as they should do; the cause being that, after an inside chaser is cut by the hub, it has to be turned around to be

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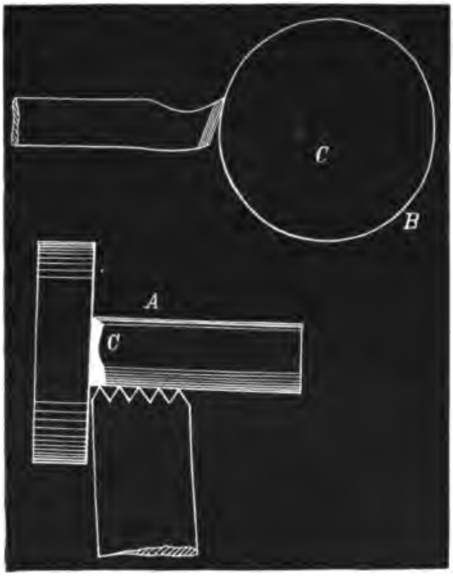
placed in a position to cut, which turning reverses the direction in which its teeth slant.

Such a chaser will, it is true, cut a right-hand thread, but only by so tilting the teeth that only their edges have

Fig. 40.



contact with the bore of the work. Now since an inside chaser would be too keen and would hence rip into the work if it possessed any top rake, and since it usually requires to have a slight degree of negative top rake, tilting it causes it to cut a thread shallower than the depth of its own teeth, as already explained with reference to outside chaser. It follows then that it is of great importance to cut a right-hand inside chaser from a left-hand hub, and *vice versâ.*

In the absence of a hub an inside chaser may be cut by a piece of wrought-iron having a hole and a slot cut in

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the side of the hole. If then the chaser is forged straight ready for use and fastened into the slot, and the hole is tapped out, the tap will at the same time cut the teeth upon the chaser, a right-hand tap cutting a right-hand chaser. In adopting this plan, however, it is proper to use a tap of a diameter large in proportion to the pitch of the thread, otherwise the teeth of the chaser will be hollowed too much in the direction of their length, and will in consequence jar or chatter when cutting, especially when in use upon long bores, in which cases the teeth cut at a long distance out from the lathe rest. It is a good plan to bore a quarter-inch hole in the top face of the lathe rest, and to insert therein a small pin, against which the edge of the chaser opposite to the teeth may be pressed, so that the pin will act as a fulcrum to force the teeth into their cut.

Inside threads are started by pressing the teeth lightly against the bore of the work, and moving the chaser forward at about the requisite speed. The corner of the bore of the work should be slightly rounded off (as should also the corner on the end of work to be chased with an outside thread) to prevent the chaser teeth from catching against it.

Either an inside or an outside chaser may be employed to cut a double or even a triple thread. A double thread is one in which the distance from one thread to the next is only one-half the actual pitch of the thread. Thus supposing a thread of five to an inch to be started in a screw-cutting lathe, and that the tool point is then moved laterally so as to cut another groove between the grooves first cut, there will be two threads each of a pitch of five to an inch, and yet the distance from one thread to the next will only be one-tenth of an inch, hence a chaser of the latter pitch may be used to cut up the two threads, thus producing a double thread whose actual, is twice that of its apparent, pitch.

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Beginners should always stop the lathe and examine a single inside thread as soon as it is struck, for it is an easy matter to cut a double female thread in consequence of moving the chaser too fast, nor will the error be discovered until the thread is finished.

Double outside or male threads, to be cut by hand, can be most easily started by the chaser, moving it twice as fast as would be required for a single thread, rounding off the corner of the bolt end and taking care to cut principally with the hindermost teeth.

The proper temper for the teeth is a deep brown, or, for unusually hard metal, a straw color. For chasing wrought-iron, the lathe may be run so that the teeth will perform about 40 feet, for steel about 30 feet, for cast-iron 50 feet, and for brass about 80 feet, of cutting per minute.

The quickest way to cut a number of threads upon bolts requiring to have a true thread and of an ordinarily good fit, is to take about two good cuts with a screw tool in the lathe, and then fastening a solid die in the vise to screw the bolt through the solid die by the aid of a wrench on the bolt head. The cuts taken in the lathe will make the bolt enter the die easily and true, while the die will insure correctness of size in the thread; bolts threaded thus may be screwed at least four times as quick as by finishing them entirely in the lathe.

In making a hub or master-tap for use to tap solid dies, cut in it as many flutes as will leave sufficient strength to the teeth, and let the number be an odd one.

To clean rusted threads on studs in their places, or to remove burrs from them, make a steel nut and file two slots through it after the manner of a solid die; and, after tempering it to a light straw color, screw it along the threads requiring to be cleaned, applying a little oil. It must not be forgotten, that as steel shrinks in hardening, the tap used for this purpose should be a little above the standard size, or else worked sufficiently in the nut to cut it out larger than the normal size.

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TO CALCULATE THE GEAR-WHEELS NECESSARY TO CUT A THREAD IN A LATHE.

The pitch of a thread is the distance or width from one thread to the next one, and is usually measured by the number of threads contained in an inch of length, and is therefore spoken of as a pitch of so many threads to the inch. In measuring the pitch of a thread, the rule is generally applied upon the tops of the thread; but it must be borne in mind not to count the thread at the beginning of the inch, since the pitch of the thread is the number of thread *tops less one* than there are in an inch of the thread. What is called (as applied to its screw-cutting wheels) a single geared lathe, is one in which the driving gear is either fastened upon and revolves with the mandril or spindle of the lathe, or else is driven by an intermediate gear-wheel of such a size that the driving gear, though not fast upon the lathe spindle or mandril, still makes the same number of revolutions per minute as does the mandril, while at the same time no two wheels (on such a lathe) of different diameters run side by side, making an equal number of revolutions in a given time.

In such a lathe we have only to consider the driving wheel or gear and the gear upon the feed screw of the lathe, the others or intermediate wheels having no effect or influence (upon the thread to be cut) other than to make up the distance between the driving and feed screw gears, and thus to communicate the motion of the one to the other. Hence, having ascertained what sized wheel is required for the driving wheel and on the feed screw, we may connect them together by any wheel or wheels that will answer irrespective of their sizes.

It will be readily perceived, then, that if the driving gear and the feed screw gear contain respectively the same number of teeth, the lathe would be geared to cut a thread of the same pitch as the pitch of the thread on the feed

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screw of the lathe, because the feed screw would revolve at the same speed as the lathe did. Now, in exact proportion as the feed screw revolves slower than does the lathe spindle or mandril, will the thread cut by the lathe tool be finer than that on the feed screw, and *vice versâ;* hence we have—whereby to find the wheels necessary to cut a thread of a required pitch in a single geared lathe—the rule:

Divide the pitch of thread required by the pitch of the feed screw, and use the product as a divisor to the number of teeth contained in the wheel already upon the feed screw, and the last product will be the number of teeth required in the driving wheel.

Example. I require to cut a thread, pitch 8 to an inch, the pitch of the feed screw being 4 to an inch, the wheel upon the feed screw containing 80 teeth.

$8 \div 4 = 2$; then $80 \div 2 = 40 =$ the number of teeth required in the driving wheel.

The usefulness of this rule lies in that when the feed screw is in use for ordinary feeding, it usually requires the largest gear upon it, while the driving wheel will be one of the smallest, which occurs because the feed of a lathe is usually finer than the threads ordinarily cut in it; hence, while it is almost always necessary to remove the driving gear, it is rarely necessary to remove the feed screw gear unless the pitch of the thread required is to be coarser than that of the feed screw of the lathe, in which case we adopt the following rule:

Divide the pitch of the thread required to be cut by the pitch of the feed screw, and multiply the product by the number of teeth in the driving gear; the last product will be the number of teeth required upon the feed screw gear.

If there is no wheel upon the feed screw or the driving spindle, we use the rule:

Divide the pitch of thread required by the pitch of the feed screw, and the product will be the proportion required

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between the number of teeth on the driving and on the feed screw gear.

Example. It is required to cut a thread of 8 to an inch in a lathe whose pitch of feed screw is 4 to an inch: what number of teeth must the driving gear and feed screw gear respectively contain?

Pitch of thread to be cut.		Pitch of feed screw.				
8	$\div$	4	=	2	=	Proportion between the required gears.

Which means that the proportion between the gears must be two to one, or in other words, one wheel must contain twice as many teeth as the other. We may therefore pick out from our gear wheels any two wheels in which one contains twice as many teeth as the other, and then say, "Since the thread to be cut is finer than the thread upon the feed screw, it is evident that the feed screw must revolve slower than does the lathe spindle or driving gear; hence the largest of our two selected wheels must be placed upon the feed screw, and the other must be placed upon the lathe spindle or mandril."

The term *Compound* or *double geared*, as applied to the screw-cutting gear of a lathe, means that there exists, between the gear wheel which is fastened to, and revolves with, the lathe spindle, and the feed screw, two gear wheels of different diameters and revolving side by side, at the same number of revolutions, by reason of being fixed upon the same sleeve or axis. The object of this arrangement is to make, between the speed at which the lathe mandril or spindle will run, and the speed or revolutions at which the feed screw will run, a greater amount of difference than is possible in a single geared lathe, and thus to be able to cut threads of a coarser pitch than could be cut in the latter. This is usually accomplished by providing two intermediate wheels of different diameters, both being held by a feather to a sleeve revolving upon an adjustable pin provided for the purpose.

It is obvious that the smallest of these compounded or

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coupled wheels will gear into and with the wheel or gear on the feed screw; and that the changes of gear may be made upon the gear running on the lathe mandril and that running on the feed screw, without disturbing the pair of intermediate (and compounded) gears referred to. In many cases, however, only the wheel upon the feed screw need be changed, since a wide range of pitch may be obtained by changing that wheel only.

To find the number of teeth in the wheel required to be placed on the feed screw, we have the following rule:

Divide the pitch to be cut, by the pitch of the feed screw, and the product will be the proportional number. Then multiply the number of teeth on the lathe mandril gear by the number of teeth on the smallest gear of the compounded pair, and the product by the proportional number, and divide the last product by the number of teeth in the largest wheel of the compounded pair, and the product is the number of teeth for the wheel on the feed screw.

Suppose, for example, the gear on the lathe mandril contains 40 teeth running into the largest of the compounded gears which contains 50 teeth, and that the small gear of the compounded pair contains 15 teeth; what wheel will be required for the feed screw—its pitch being 2, and the thread requiring to be cut being 20?

$$\underset{\text{Pitch required.}}{20} \div \underset{\text{Pitch of feed screw.}}{2} = \underset{\text{Proportional number.}}{10}$$

Then—

$$\underset{\text{Mandril gear teeth.}}{40} \times \underset{\text{Small compound gear.}}{15} \times \underset{\text{Proportional number.}}{10} \div \underset{\text{Large compound gear.}}{50} = 120$$ = the number of teeth required upon the wheel for the feed screw. In the above example, however, all the necessary wheels except one are given; and since it is often required to find the necessary sizes of two of the wheels, the following rule may be used:

Divide the number of threads you wish to cut by the

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pitch of the feed screw, and multiply the quotient by the number of teeth on one of the driving wheels, and the product by the number of teeth on the other of the driving wheels; then any divisor that leaves no remainder to the last product is the number of teeth for one of the wheels driven, and the quotient is the number of teeth for the other wheel driven.

[In this rule the term "wheel driven" means a wheel which has motion imparted to it, while its teeth do not drive or revolve any other wheel; hence the large wheel of the compounded pair is one of the wheels driven, while the wheel on the feed screw is the other of the wheels driven.]

Example. It is required to cut 20 threads to the inch, the pitch of the feed screw being 2, one of the driving wheels contains 40 teeth and the other 15:

Pitch required to be cut.		Pitch of feed screw.		Teeth in one driving wheel.		Teeth in other driving wheel.		
20	$\div$	2	$\times$	40	$\times$	15	=	6000.

Then, $6000 \div 50 = 120$; and hence one of the gears will require to contain 50 and the other 120 teeth; if we have not two of such wheels, we may divide by some other number instead of 50.

Thus: $6000 \div 60 = 100$; and the wheels will require to have, respectively, 60 and 100 teeth.

If there are no wheels on the lathe we proceed as follows:

Divide the pitch required by the pitch of the feed screw; the quotient is the proportion between the revolutions of the first driving gear and the feed screw gear.

Example. Required the gears to cut a pitch of 20, the feed screw pitch being 4; here $20 \div 4 = 5$; that is to say, the feed screw must revolve five times as slowly as the first driving gear; we now find two numbers which, multiplied together, make five: as $2\frac{1}{2} \times 2 = 5$; hence one pair of wheels must be geared $2\frac{1}{2}$ to 1 and the other pair 2 to 1, the small wheel of each pair being used as drivers, because the thread required is finer than the feed screw.

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CHAPTER V.

GENERAL OBSERVATIONS ON LATHE WORK.

In taking cuts for side faces, that is, faces parallel to the face plate of the lathe, the cuts may be commenced at the centre and carried to the outer diameter of the work, or commenced at the outer and continued to the centre. It is better, however, to begin the finishing cuts at the largest diameter, because the shavings or turnings will cause less strain to the tool in consequence of its having to bend them; the reasons being explained in Figures 24 and 25, and by the remarks accompanying them.

If a tool for wrought-iron gets dull, the shavings will appear ragged instead of clean cut, and the tool will require unusual power to force it to its cut.

When a tool is placed so high in the lathe as to require forcing into its cut, it is apt when it commences to cut to dig into the work.

If a tool cuts at one revolution of the lathe and skips the cut at the next, it is either that the tool is set too high, has too much top rake, considering its distance from the tool post, or the slide rest is slack upon the slides. Skipping will also occur from a very dull tool, but the cause in that case is too apparent to require remark. Very slight work requires to be cut with a tool having plenty of bottom rake and a very slightly rounded point.

Lathe tools for use on copper, lead, tin, and similar soft metals should have a great deal of top rake, their general outline being similar to tools for wrought-iron.

Tools which revolve while the work remains stationary should perform their cutting at about 15 feet per minute.

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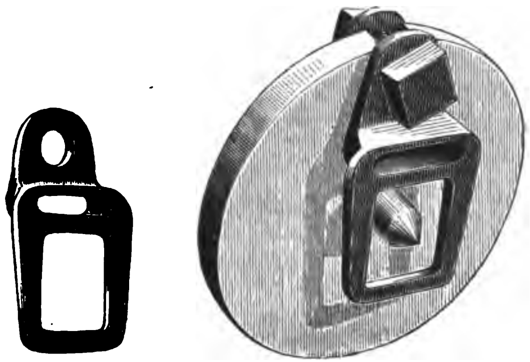
Both the roughing out and finishing of large wrought-iron should be done with a liberal application of water or soapy water to the work. Small wrought-iron work may be roughed out dry, but should be finished with soap water applied. Screws on wrought-iron *must* be cut with a liberal application of oil, but they may be finished with soap water. Copper will cut easily and cleanly when oil is applied.

Cast-iron will cut with a bright smooth polish, if water is applied and the cutting speed is about 7 feet per minute.

H. S. MANNING & CO.'S LATHE DOGS AND DRIVERS.

In turning a number of bolts, time may be saved by clamping to the face plate of the lathe a driver having a hole in it to suit the shape of the heads of the bolts, thus

Fig. 41.



obviating the necessity of having to screw on a carrier or driver to each bolt head. The pattern illustrated in Fig. 41 is suitable for square-headed or hexagon head bolts.

Fig. 42 represents a lathe carrier or dog, as it is sometimes called. When used upon finished work, a piece of

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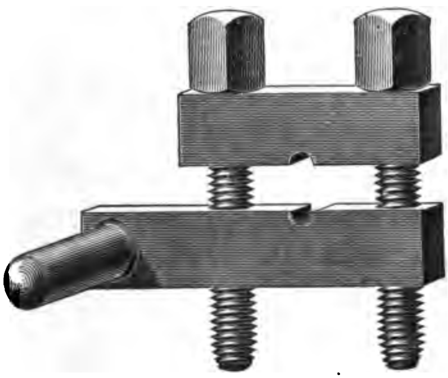
copper should be placed between the end of the screw and the work to prevent damage to the latter.

Fig. 42.

In cases where very heavy cuts are to be taken, two of these carriers may be used. In such case they should first be screwed up, not too tightly, and after starting the lathe and putting on a cut to bring them both to a bearing against the driving pin, the lathe may be stopped and both the carriers screw up tightly. For driving square shafts in the lathe, the clamp shown in Fig. 43 is employed. The jaws should be screwed down even so as to bear evenly on the work and not to bend the jaws of the clamp.

Fig. 43.



EMERY GRINDER.

No machine shop should be without its emery grinder, which saves a great deal in files as well as in time.

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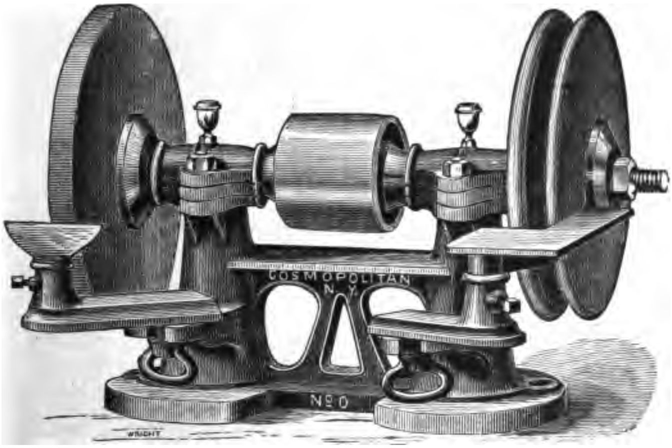
Articles that are hardened may be cut with an emery wheel which would otherwise require to be softened, since they could not be ground upon a grindstone, because a stone has its corners rounded, and does not keep true. Fig. 44 represents an emery grinder intended to carry

Fig. 44.



wheels up to about 12 inches diameter, which is large enough for machine shop purposes.

To true up emery wheels a diamond tool is provided, such tools being kept on hand by H. S. Manning & Co. Some kinds of emery wheels are, however, turned by a red hot iron, while still others may be trued by wetting the periphery of the wheel and applying a file.

H. S. MANNING & CO.'S CENTERING MACHINE.

The centering machine (Fig. 45) is employed to centre, centre-drill and counter-sink, at one and the same operation, bolts, spindles and shafts, etc., which are to be turned in the lathe. It is a great labor-saving tool, doing ten times as much work as can be done by hand. The chuck is a universal one, so that the work requires no setting.

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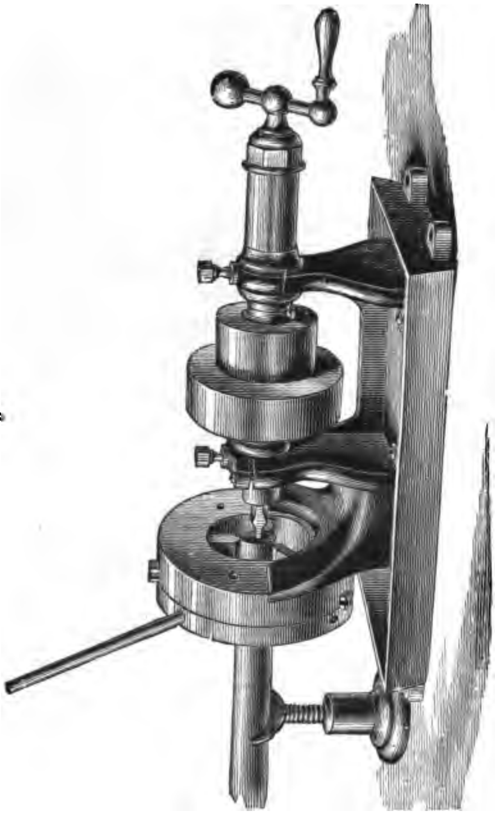
The combined drill and counter-sink is fed by the handle at the end of the running head. The drill should be run at about 300 revolutions per minute, and for use on wrought-iron and steel should, while cutting, be supplied freely with oil.

Fig. 45.



H. S. MANNING & CO.'S CENTERING MACHINE.

In fitting cones or tapers to their holes they should be marked by either a very faint application of red marking, or else have a stripe of chalk rubbed smoothly on them from end to end.

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Red marking is made by mixing to a *thick* paint dry Venetian red and common lubricating oil.

All work requiring to be finely fitted requires the use of marking to show where it touches.

In fitting valves to their seats, be sure that the cone fits well upon the smallest diameter of the seat, since that is the area from which the valve and lever is calculated.

Tools for turning chilled cast-iron may be made as follows: forge a tool of wrought-iron and over the cutting end, cast chilled iron composed of charcoal iron No. 5. Then grind the tool to the usual shape, but with very little top rake.

If piston rod glands fit rather tight, they may be eased by rubbing them up and down the rod, giving them at the same time a slight twisting motion. A few drops of oil should be supplied to the rod to prevent the glands from seizing or cutting.

A gland should be chucked in the lathe by the flange, so that the bore and the outside diameter may be turned at one chucking, and thus be true, each with the other, without depending upon the truth of a mandril.

LATHE WORK.

The centres of a lathe should be turned both to an equal taper, a gauge being used for the purpose. The running centre should be tempered to a blue, and the standing centre to a brown color. If the holes in the headstock or tailstock of the lathe into which the centres fit are out of true, as is sometimes the case, a centre punch mark should be made upon the diameter of the exposed part of the centre, and another upon the end face of the spindle, and the centre always placed so that the two "centre pops" are opposite to each other; thus the centres will run true whether the taper holes into which they fit are true or not.

After the centres are hardened, care should be taken to

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properly clean their taper parts so that there may be no dirt or grit upon them to cause them to run out of true. If the running centre is removed from the headstock, as is sometimes necessary in boring and for other purposes, the hole into which the centre fits should be plugged with a piece of waste or rag to prevent it from becoming filled, or partly so, with shavings.

Plain work that is not easy to handle may be marked off for the centre punch by a pair of compass calipers, and light work as follows: Place upon a planed surface a pair of parallel strips or pieces, one being under one end, the other under the other end of the work; then set the point of the scribing block scriber as near the centre of the work as the eye can determine, and draw a line across the end of the work; then turn the latter upside down and mark another line across its end; the work must then be turned a quarter revolution, so that the next line marked by the scriber will be at about right angles to the two lines already drawn, which being done and the line drawn, the work must again be turned upside down and the final line drawn, when the junction of the lines where they cross each other or the centre of the square formed by their crossing each other will be the centre of the work, and may be counterpunched. It is obvious, however, that if the scriber be placed at the centre of the iron, only two such lines will be visible, the point of their intersection being, in that case, the centre of the work.

The centres of all lathe work should be cleared at the extreme central part, so that such part will not revolve against the points of the lathe centres, which would cause the work to run out of true after running a short time in the lathe.

Such clearance is best accomplished by drilling a small hole in the central part of the work centres; it may, however, be done by using a centre punch of a more acute taper than is the lathe centre, or by cutting out the centres

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by means of a square centre, as will be hereafter described. The drilling is, however, the preferable plan, being the least liable to cause the centres of the work to wear out of true.

For this purpose the universal chuck and a twist drill about a sixteenth of an inch in diameter are the most desirable tools, they being purchasable from any store keeping machinists' supplies. The chuck must be screwed on to the running spindle of the lathe; and the drill being fastened in the chuck, the work is placed so that the point of the drill is in one of the centres and the centre of the back head of the lathe is in the other centre. Then, by starting the lathe and holding the work still by the left hand while the right hand is gently screwing out the back lathe centre, the work will be forced over the revolving drill, thus drilling the hole referred to. While the drilling is being performed, the drill should be freely supplied with oil to assist it in cutting and to prevent it from wearing away and becoming dull. It is very important, during this operation of centre drilling, to relax, every few seconds, the hold upon the work sufficiently to permit it to make about a third of a revolution, which may be done while the other hand is supplying oil to the drill. The object and effect of this is to cause the centre drilling to be true, which otherwise it would not be, especially if the work is comparatively heavy, or heavier on one side than on another.

If, however, the work requires to run very true, as in the case of recentering work which has once been turned, the square centre must be employed to cut the centre of the work true to the circumference. A square centre is a centre fitted to the lathe in the same manner as the common centre, but having four flat sides ground upon its conical point, all four sides meeting at the point, and having sharp edges. The taper of these sides should be more acute than is the taper of the lathe centre, so that

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the centre cut in the work by the square centre shall not bear upon the point of the lathe centre, and cause it to run, in time, out of true. The square centre should be hardened to a straw color, and may then be used to simply countersink centres which have been centre-drilled, in which case it is put into the centre hole of the head of the lathe and revolved at a high speed (by the lathe) while the work is forced up to it by winding out the back centre, the work being between the two centres. To centre work very truly, it is employed as follows: The square centre is put in the tailstock spindle of the lathe, in the same way as the ordinary centre is placed, the work having a dog or driver placed on it, as if the intention were to turn the work; it must then be placed in the lathe between the centres. A piece of iron or steel, having a hollow or flat end (as, for instance, the butt end of a tool) must then be fastened in the tool post of the lathe; then the lathe may be started and the tool end wound against the end of the work (close to the square centre) until it touches it and forces it to run truly, in which position the tool end is left, while the square centre is fed up and into the work until the latter is true, when the operation will be completed. Before any turning is done to the diameter of any lathe work which runs between the centres, the ends of such work should be made true; because if there be a projecting part on the end, or if the latter is not quite true, the centre gradually moves over to the lowest side.

The work being centre-drilled, it must be placed in the lathe, with a driving dog on one end, the back centre being screwed up only just so tight that the work may be moved by the fingers, and yet it must have a firm bearing against the lathe centres. The hand rest should then be placed as close to the work as possible without touching it, when the ends of the work must be trued up. The object of first truing the ends is to prevent the centres in the work from wearing on one side more than the other, as they

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would do if one side of the end face of the work was, at either end, higher than the other. Having squared each end of the work, it must be taken from the lathe, and the burr left by the turning tool around the centre filed off, when the work will be ready to countersink, that is, to bevel off the edge of the hole made by the centre-drilling, and thus to form a recess in which the lathe centre will fit. Many practical men will countersink by simply centre-punching, or else neglect the operation altogether, and force up the back centre of the lathe and thus wear a countersink in the work. The wear and damage caused to the lathe centre is sufficient condemnation of this system, unless it be applied to work that requires to be reduced in size regardless of its being either true or uniform, and this should be done in a lathe used only for such work. Countersinking by centre-punching will answer very well for jobs that require sufficient work to be performed on them at each end to give them time to wear and fit the centre; and as this is nearly always the case, this system is considered sufficient for all practical purposes. It is, however, mechanically incorrect, because (even supposing the artisan to be able to grind the centre-punch true so far as roundness is concerned, and true in its bevel with relation to the bevel of the lathe centre), unless he holds the centre punch so that the centre line of its length is dead true with the centre line of the work, the countersinking will be deeper on one side of the work than on the other, and hence will throw the work out of true. It will, however, right itself after running a little time in the lathe. Now it is quite true that the amount to which the work will thus be thrown out of true is very slight, and (as stated) soon rights itself; but even when the end of the work running on the still or dead centre has worn itself true, it must be turned end for end in the lathe before the other end will become true. Then, again, when there are many pieces of work to countersink, that

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operation may be as quickly performed by means of the square centre as with the centre punch, while the square centre will cut true and uniform. The only possible claim that countersinking by centre-punching can possess is the saving of the time required to place the square centre in the lathe; for after it is once placed there, the operation may be as quickly performed in the one case as in the other.

Countersinking by the square centre is performed by making the square centre the running centre of the lathe, and by feeding the work up to it by the back lathe centre, as described in the instructions upon centre-drilling.

All work which requires to be turned at both ends (and hence must be turned or placed end for end in the lathe) should be roughed out (that is, cut down to nearly the required size) all over before any part of it is finished, or, when turned end for end in the lathe, the part first turned up will run out of true with the part last turned up, though the lathe centres may be correctly placed. This may be caused by the centres of the work moving a little as they come to their bearings on the lathe centres, or in consequence of breaking the skin of the work; for nearly all work alters in form as its outside skin is removed, especially work in cast-iron.

There is no better method whereby to finish lathe work than by filing it lightly with a smooth and dead smooth file; the duty assigned to the file should not be that of reducing the size of the work more than is necessary to the finishing process. The lathe tool should be made to finish the work as true and as smoothly as possible; the lathe should then be run at a high rate of speed and the file applied lightly to the work. It will not do to hold the file still because the filings will in that case become locked in the teeth of the file and will cut scratches in the work, hence the file must be moved across the work the same as though the latter was stationary. To prevent the filings from lodging in the file teeth and scratching the work, we

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may either oil or chalk the surface of the file teeth, and in either case, clean the file so soon as it becomes at all clogged with filings. Round corners or sweeps must be finished with the lathe tool, since a file applied to them would only cut scratches in them. It must be borne in mind that the tendency of a file applied to revolving work is to cut the soft parts of the metal more readily than the harder parts, and hence, to make the work out of round and out of true; these effects will not be appreciable if the finishing cuts are taken properly smooth and fine and clean, and the file is employed to merely erase the tool marks.

EMERY CLOTH AND PAPER.

For ordinary work the ordinary grades of emery paper and cloth may be employed, the finest being flour emery cloth or paper. The same grade of emery will cut coarser if placed on cloth than if on paper, because the surface of the cloth is not so smooth and even as that of the paper, and the consequence is that the grains of emery which are attached to the high spots on the cloth present a keener cutting edge and surface to the work than the rest of the surface. The main advantage of emery cloth lies in that it will wear longer because it is not so apt to tear. To fit emery cloth or paper for very fine work it should be used upon the work until the entire surface becomes worn even and glazed; the more it is worn and glazed the finer it will finish, and this remark applies equally to all kinds of emery cloth and paper, or crocus cloth. There is, however, an emery paper much finer than any other, its grades ranging from 1 to 0000, and it will produce a finish so fine as to give the work a finish and appearance equal to the finest silver or nickel-plating.

The method of using to produce a really fine finish is to revolve the work very fast in the lathe and to keep the emery paper moving rapidly, endwise of the work, so that the marks shall cross each other at a very obtuse angle.

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The coarser grades of cloth should be applied first, each successive grade being used until it has entirely removed the marks left by the grade previously used. The final polish is given by number 0000 paper moved laterally along the work very slowly, and under a very light pressure. To prepare the paper for the final finishing we must take the 0000 paper, and, giving the work a coating of oil barely sufficient to dull the polish, apply the paper, continually reversing its position in the hand so that all parts will become worn, the effects of the slight oiling being to cause the particles of metal cut off the work to adhere to and form a glaze upon the surface of the emery paper, and all metals polish best by being rubbed with a glazed surface composed of minute particles of the same metal as themselves; it follows, then, that the more emery paper or cloth becomes worn the finer it will polish.

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CHAPTER VI.

TURNING ECCENTRICS.

If an eccentric has a hub or boss on one side only of its bore (as in the case of those for engines having link motions, where it is desirable to keep the eccentrics as close together as possible in order to avoid offset either in the bodies or double eyes of the eccentric rods), the first operation to be performed in turning it up is to chuck it with the hub side towards the face plate of the lathe, setting it true with its outside diameter (irrespective of the hole and hub running out of true), and to then face up the outside face. It must next be chucked so that the face already turned will be clamped against the face plate, setting the eccentric true to bore the hole out, and clamping balance weights on the face plate, opposite to the overhanging part of the eccentric. The hole, the face of the hub, the hub itself (if it is circular), and the face of the eccentric must be roughed out before any of them are finished, when the whole of them may be finished, to the requisite sizes and thicknesses. The eccentric must then be turned about and held to the chuck-plate by a plate or plates clamping the hub or boss only, the diameter of the eccentric being set true to the lines marked to set it by; then the diameter of the eccentric may be turned to fit the strap, the latter having been taken apart for that purpose. The reason for turning the strap before the eccentric is turned is (as may be inferred by the above) that the strap can be fitted to the eccentric while the latter is in the lathe, whereas the eccentric cannot be got into the strap while

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the strap is in the lathe. By this method, the outside of the eccentric will be turned true with a face that has been turned at the same chucking at which the hole was bored; while the eccentric will stand sufficiently far from the chuck to permit of the strap being tried on when it is necessary. And, moreover, the skin of the metal will have been removed on three out of the four faces before either of the working parts (the bore and the outside diameter) is finished; and as a consequence, the work will remain true, and not warp in consequence of the removal of the skin. Furthermore, upon the truth of the last chucking only will the truth of the whole job depend; and if the face plate of the lathe is a trifle out of true, the eccentric will only be out to an equal amount. It is not an uncommon practice (but a very reprehensible one) to face off the plain side of the eccentric, and to then bore the hole and turn the outside diameter, with the plain face clamped in both cases to the face plate. The fallacy of this method lies in the fact that, by such a procedure, the eccentric will be, when finished, out of true to twice the amount that the face plate is out of true.

The strap should have a piece of thin sheet tin placed between the joint of the two halves before it is turned out, which tin should be taken out when the turning is completed, and the strap bolted together again. The size for the eccentric will then be from crown to crown of each half of the strap.

The object of inserting the tin is to make each half of the eccentric bed well upon the crown, and to prevent it from bearing too hard upon the points, as all straps do if the joint is not kept a little apart during the boring process. If the eccentric is already turned, an allowance may be made for the thickness of the sheet tin between the strap joint by placing a piece of the same tin beneath one of the caliper points when gauging the eccentric to take the size for the strap.

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Eccentrics having a proportionally large amount of throw upon them are sometimes difficult to hold firmly, while their outside diameters are being turned to fit the strap, because the hub which is bolted against the face plate is so far from the centre of the work that, when the tool is cutting on the side of the eccentric opposite to the hub, the force of the cut is at a considerable leverage to the plates clamping the eccentrics; and the latter are, in consequence, very apt to move if a heavy cut is taken by the tool. Such an eccentric, however, usually has open spaces in its throw, which spaces are placed there to lighten it; the method of chucking may, under such circumstances, be varied as follows: The outside diameter of the eccentric may be gripped by the dog chuck, if the dogs of the chuck project far enough out to reach it (otherwise the dogs may grip the hub of the eccentric), while the hole is bored and the plain face of the eccentric turned. The eccentric must then be reversed in the lathe, and the hub and the face on that side must be turned. Then the plain face of the eccentric must be bolted to the face plate by plates placed across the spaces which are made to lighten the eccentric, and by a plate across the face of the hub. The eccentric being set true to the lines may then be turned on its outside diameter to fit the strap; to facilitate which fitting, thin parallel strips may be placed between the face plate and the plain face of the eccentric at this last chucking. It will be observed that, in either method of chucking, the outside diameter of the eccentric (that is to say, the part on which the strap fits) is turned with the face which was turned at the same chucking at which the hole was bored, clamped to the face plate. In cases where a number of eccentrics having the same size of bore and the same amount of throw are turned, there may be fitted to the face plate of the lathe a disk of sufficient diameter to fit the hole of the eccentric, said disk being fastened to the face plate at the required distance from the centre of

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the lathe to give the necessary amount of throw to the eccentric. The best method of fastening such a disk to the face plate is to provide it with a plain pin turned true with the disk, and let it fit a hole (bored in the face plate to receive it) sufficiently tightly to be just able to be taken in and out by the hand, the pin being provided with a screw at the end so that it can be screwed tight, by a nut, to the face plate. The last chucking of the eccentric is then performed by placing the hole of the eccentric on the disk, which will insure the correctness of the throw without the aid of any lines on the eccentric which may be set as true as the diameter of the casting will permit, and then turned to fit the strap. A similar disk, used in the same manner, may be employed on cranks, to insure exactness in their throw.

TURNING CRANKS.

A crank having a plain surface on its back should have such surface planed true. The large hole should be bored first, the crank being clamped with its planed surface to the chuck plate of the lathe, when the hole may be bored and the face of the hub trued up. To bore the hole for the crank pin, clamp the face of the hub of the crank, which has been trued up, against the plate of the lathe (the crank pin end of the crank being as it were suspended); then bolt two plates to the chuck plate, one on each side of the crank at the end to be bored, and place them so that their ends just come in contact with the crank end, as shown in Fig. 46, *a a* being the chuck plate, B the crank, C the clamp holding the turned face of the inside hub of the crank to the chuck plate, and *d d* the plates steadying the end of the crank to be bored, so that it shall not move its position on the face plate (or chuck plate) from the pressure of the cut, and E a weight bolted to the chuck to counterbalance the heavy end of the crank. It is obvious that, if the crank be a heavy one, two or more plates may be used in place of the plate or clamp C.

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A crank chucked in this manner will be practically true providing the chuck plate be true, even if the cut taken off the back by the planer were not true, or even though there had been no cut taken off the back, and the crank had, in consequence, been sprung in the first chucking; because the face of the hub (or boss, as it is sometimes called) will, under any circumstances, be true with the hole, both having been turned at one chucking; and even if the crank were twisted in chucking, the face will follow the hole and remain practically true with it. This face,

Fig. 46.

being in the second chucking bolted to the face plate of the lathe, will be held as true as is the face plate, and cannot spring from the pressure of chucking; neither can the crank pin end spring in the second chucking, because it does not receive any strain from either bolts or clamps. Furthermore, if the face plate is out of true across its face (that is, hollow or rounding), the last hole bored in the crank will, if chucked in this manner, be out of true to only the same degree as is the face plate.

If, on the other hand, both holes of the crank are bored

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by clamping the planed face of the crank against the face plate, merely turning the crank end for end to bore the last hole, the holes in the crank will be, when finished, out of true with each other to twice the amount that the face plate of the lathe is out of true, or to twice the amount that the planed surface is itself out of true, from being sprung in chucking on the planer, from having its skin removed, or from other causes. If the face plate of a lathe is known to be hollow or round in the plane of its face, a piece of paper or other substance, of the thickness necessary to compensate for the defect, may be placed behind the crank and between it and the face plate, in the position requisite to effect such compensation.

Weights sufficient to counterbalance the overhanging end of the crank should be bolted to the face plate on the side opposite to such end, as shown at E, Fig. 46.

TO CHUCK A CROSSHEAD.

In chucking a crosshead, the lines given to it in the marking off are of very little value, because crossheads being generally small, the lines are not sufficiently long to form very accurate guides, and we have therefore to make the method of chucking as accurate as possible. One of the best, if not the best, lathe appliances whereby to insure that holes bored, or faces or flanges turned, shall stand at a right angle one to another is the angle plate denoted by C in Fig. 46 *a*, which is a casting having two planed faces, one at a right angle to the other, so that when one of its faces is bolted against the face plate of the lathe the other shall stand at a right angle to the said face plate, or in other words, parallel to the centre line of the lathe spindle. So long then as the face plate of the lathe and the faces of the chuck remain true we have but to bore one hole of the crosshead (or one flange of the elbow, as the case may be) true, and turn the face surrounding that hole, and to then chuck the crosshead by bolting the

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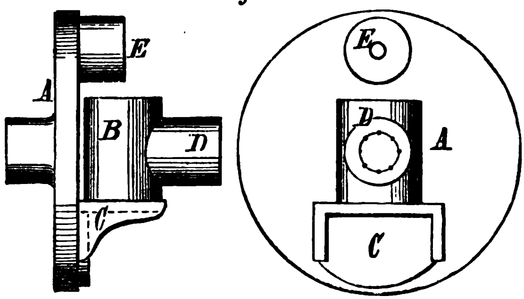
turned face to the angle plate at the second chucking, to insure the work being turned true. Angle plates are, however, apt to get out of true, especially if in setting the chuck it is driven into its position by hammering it, without the interposition of a wooden block, for such hammering stretches the skin of the iron of the chuck and warps it from the causes to be explained in our remarks on pening.

In Fig. 46 *a*, A represents the face plate of a lathe, and C an angle plate, that is, a plate having its two flat surfaces at a right angle to each other. It is evident that if the work has the hole parallel with the line B bored, and the end faces round that hole trued with it, we have only

Fig. 46 *a.*



to bolt the angle plate C to the face plate A of the lathe, and then to bolt one of the turned faces of our work to the face of the angle plate, and set the latter so that the parallel stem D of the work runs true; and then it will be so set that the holes, if bored true with the tool, will stand at a right angle to each other. In all cases, however, in which an angle plate is used, or in which, from other causes, there is a greater amount of weight on one than on the other side of the face plate of the lathe, there should be bolted to the latter a weight sufficient to act as a counterbalance, such a weight being shown at E, in Fig. 46 *a*; otherwise the work will be bored and turned slightly oval. To insure

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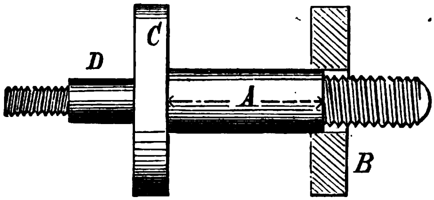
truth in the chucking it is necessary to bore out one hole; and having faced up the faces at the end of that hole, to then chuck the work with a parallel mandril fitting neatly into and projecting from the hole already turned. The work must be so set that the mandril stands true or parallel with the face plate of the lathe; this may be done in conjunction with the use of the angle plate, thus insuring accuracy in the chucking of the work.

In boring a number of lever arms or other work having holes requiring to be of precisely the same distance apart, we bore and finish one with great exactitude. Then after that one is bored, and the faces of the hub are faced off true with the hole, a pin, as shown in Fig. 46 *b*, should be

Fig. 46 *b.*



made, the diameter of the part A being made to neatly fit one of the holes in the end of the arms or levers, and being marked shorter in length than is the length of the lever hole into which it fits. B is a washer, turned to fit easily to the diameter of A, and C is a collar, solid with A. D is a stem, turned parallel and true; and it is a little less in length than the thickness of the chuck plate upon which the arm is to be held while the holes are being bored. Upon each end a screw is provided to receive a nut. The use of this stud is as follows: Upon the chuck plate of the lathe or boring machine, and at the requisite distance from the centre, is bored a hole to receive at a close fit the plain part D, of the stud; and into this hole that end of the stud is fastened by means of a nut. One

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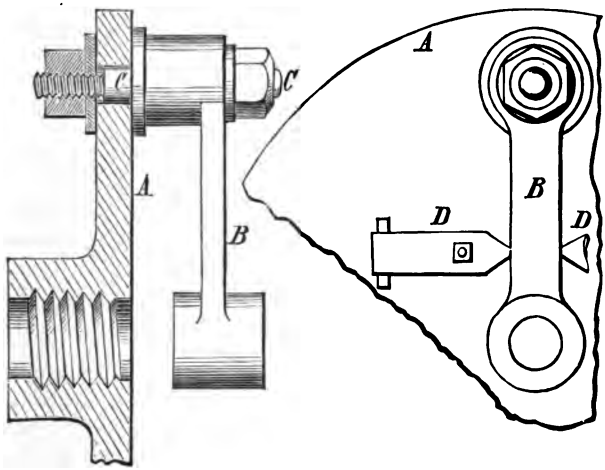
end of the lever or arm (being bored to fit the part A of the stud) is placed thereon, the stud being bolted to the chuck plate while the hole at the opposite end is being bored: thus insuring that the holes are exactly the same distance apart in all the levers. The manner of chucking is shown in Fig. 46 *c*, in which A represents a portion of the chuck, B the lever or arm to be bored, C the stud, and D D the plates bolted against the chuck so that their ends contact with the stem of the work to prevent it from

Fig. 46 *c.*



moving sideways during the operation of boring. The use of this stud, modified in shape to suit the work, is also applied to the turning of cranks, eccentrics, and other similar work, requiring unusual exactitude in the position of a hole or holes, or of a diameter in its position relative to a hole.

TURNING PISTONS AND RODS.

A piston should first be bored to receive the piston rod. The next operation is to rough out the body of the piston

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rod and to then fit it to the piston. The piston is then made fast to the rod, by the key, the nut, or by riveting, as the case may be, and the piston and rod should then be turned between the centres. By this means, the piston is sure to be true with the rod, which would not be the case if the piston and rod were turned separately. In turning the piston follower, that is, the disk which bolts to the piston head to retain the rings in their places, slack back the dogs or jaws of the chuck after the roughing out is complete, taking the finishing cuts with the jaws clamped as lightly as possible upon the work; because when the jaws of a chuck are screwed upon the work with great force, they spring it out of its natural shape.

PISTON RINGS.

The rings of metal from which piston rings are turned should have feet cast upon one end, which feet must be faced up true by taking a cut over them. The ring should then be chucked by bolting the faced feet against the chuck plate, so that the ring shall not be sprung in chucking, as it would be if it were held upon its inside or outside diameter by the jaws of a chuck. The inside and outside diameters of the ring may then be turned to their required dimensions, and the end face may be trued up, when the piston rings may be cut off as follows:

First introduce the parting tool, leaving the ring sufficiently wide to allow of a finishing cut after cutting the ring nearly off; introduce a side tool, shown in Fig. 21, and take a light finishing cut off the side of the ring, and then cut it off. The end face of the ring in the lathe may then be trued up by a finishing cut being taken over it, when the parting tool may be introduced and the process repeated for the next ring.

Piston rings are sometimes made thick on one side and thin on the other side of the diameter, the split of the ring being afterwards cut at its thinnest part, so that, when the

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ring is sprung into the cylinder (which is done to make the ring fit the cylinder tight and to cause it to expand as it wears, thus compensating for the wear), its spring will be equal all over and not mainly on the part of the diameter at right angles to the split, as it otherwise would be.

The process of turning such rings is to face the feet of the ring from which they are to be cut, and then turn up the outside diameter to its required size. Then move the ring on the face plate sufficiently to cause it to revolve eccentrically to the amount of the required difference between the thickest and thinnest parts of the ring, when the inside diameter should be trued out, and the rings cut off as before directed.

The object of turning the inside bore after and not before the outside diameter of the ring is turned, is that, during the process of cutting off the individual piston rings, the bore of the ring will be true, so that the parting tool will not come through the ring at one side sooner than at the other; for if this were the case, the parting tool, from its liability to spring and its broad cutting surface (parallel to the diameter of its cut), would be apt to spring in, rendering the cutting off process very difficult to perform; because if the piston ring is cut completely through on one side and not on the other, it will probably bend and spring from the pressure of the parting tool, and in most cases break off before being cut through at all parts by the tool.

The inside diameter (or bore) of piston rings is frequently left rough, that is to say, not turned out at all; but whenever this is the case, the splitting of the ring will in all probability cause one end of the ring (where it is split) to move laterally one way and the other end to move the opposite way, causing the vise hand a great deal of labor to file and scrape the sides of the ring true again. The cause of this spring is that there is a tension on the

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inside of the ring (where it has not been bored), tending to twist it, which tendency is overcome by the strength of the ring so long as it is solid; but when it is split, the tension releases itself by twisting the ring as stated.

The tension referred to is, in all probability, caused, to a certain extent, by the unequal cooling of the ring after it is cast.

Iron and brass moulders generally extract castings from the mould as soon as they are cool enough to permit of being removed, and then sprinkle the sand with water to cool and save it as much as possible. The consequence is that the part of the casting exposed to the air cools more rapidly than the part covered or partly covered by the sand, which creates a tension of the skin or outside of the casting. The same effect is produced, and to a greater extent, if water is sprinkled on one part of the casting and not on the other, or even on one part more than on another.

It has already been stated that brasses contract a little, sideways, in the process of boring, and that work of cast metal alters its form from the skin of the metal being removed; this alteration of form, in both cases, arises in the case of a piston ring from the release of the tension.

It sometimes occurs that a piece of work that is finished true in all its parts may unexpectedly require a cut to be taken off an unfinished part (to allow clearance or for other cause), and that the removal of the rough skin throws the work out of true in its various parts, as, for instance: a saddle of a lathe being scraped to fit the lathe bed, and its slides finely scraped to a surface plate; or the rest itself being fitted and adjusted to the cross slide of the saddle. If, when the nut and screw of the cross slide are placed in position, the nut is discovered to bind against the groove (of the saddle) along which it moves (the nut being too thin to permit of any more being taken off it), there is no alternative but to plane the groove in

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the saddle deeper, which operation will cause the saddle to warp, destroying its fit upon the lathe bed, and the trueness of the V's of the cross slide, and that to such an extent as to sometimes require them to be refitted.

The evil effects of this tension may be reduced to a minimum by letting the casting cool in the mould, or if they are taken from the mould while still red hot, by placing them in a heap in some convenient part of the foundry, and covering them with sand kept in that place for the purpose: and by roughing out all the parts of the work which are to be cut at one chucking before finishing any one part.

Piston rings are turned larger than the bore of the cylinder which they are intended to fit, and as before stated, sprung into the cylinder. The amount to which they are turned larger depends upon the form of split intended to be given to the ring; if it be a straight one, cut at an angle to the face of the ring, which is the form commonly employed, the diameter of the ring may be made in the proportion of one quarter inch per foot larger than the bore of the cylinder, sufficient being cut out of the ring, on one side of the split, to permit the ring to spring into the diameter of the cylinder, when the ring may be placed in the cylinder and filed to fit, taking care to keep the ring true in the cylinder while revolving it to mark it.

BALL TURNING.

The best method of turning balls, such as are sometimes used for the valves of pumps, is as follows: The ball should be cast with two round stems on it, so that the stems can be placed between the centres of the lathe while the ball is roughed out, which may be done by a front tool for brass, cutting the ball down to within $\frac{1}{32}$ inch of the required diameter, and gauging it as nearly round as can be done by the eye and a pair of calipers. If, how-

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ever, there are several balls to be turned, a gauge may be made by filing out a segment of a circle (equal to, say, $\frac{1}{3}$ of its circumference) in a piece of sheet iron about $\frac{1}{32}$ of an inch thick. After the ball is roughed out, the stems must be cut off, care being taken not to cut them off too deep. The next operation is to chuck a block, of tin or of equal parts of tin and lead, and to bore a hole in it equal to about $\frac{9}{10}$ of the diameter of the ball, into which hole the ball may be lightly tapped with a piece of wood, so that the chuck will revolve the ball and hold it sufficiently firmly to admit of its being scraped by a hand scraper.

The ball should be so placed in the chuck that the scraper marks will cross the turning marks already on the ball; and the scraper may then be applied, taking off just enough to take out the marks left by the tool when the ball was turned between the centres. The ball is then taken from the chuck by tapping the former lightly with a piece of wood, and is replaced in the chuck in such a position that the part of the ball which has just been scraped will now be inside the chuck, when the exposed half of the ball may be in turn trued up with the scraper; which being done, the ball is again removed from the chuck and replaced in such a position that the turning marks will be directly across the previous ones on that half of the ball, the scraper being then applied in the same manner as before. The ball being again removed from the chuck and replaced so that the part last scraped will be inside the chuck, the process of scraping is repeated, when the ball will have been made round except in so far that some of the scraper marks may be a little deeper than others. The positions in which the ball has been turned during the four chuckings may be clearly understood by making a comparison of the ball to the earth, the stems representing the north and south poles. The turning marks made while the ball was between the latter centres will be in the same relative position as the lines

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representing longitude. The first two turnings in the chuck will leave the turning marks in the same relative position as the lines representing latitude, and the second two turnings in the chuck will again represent the lines denoting longitude. The operation of scraping may then be repeated, the ball being reversed indiscriminately in the chuck and scraped very lightly and as evenly as possible, after which the ball cutter may be applied.

A ball cutter is a hardened steel tube with its outside edge bevelled off so as to cause the inside edge to form a cutting edge. It should be made as follows: A piece of cast steel tube about four inches long must be bored out, true and smooth, to a bore equal to about three-quarters of the diameter of the ball it is intended to cut. The outside of the tube must then be trued up so that the metal will be of equal thickness all over, which will render the tube less likely to warp during the process of hardening. The end of the cutting end of the tube must be bevelled as shown in the illustration, when the tube must be taken from the lathe and hardened right out, care being taken to dip it endwise and evenly in the water, so that its contraction in cooling may be even, which will reduce to a minimum its liability to crack or warp.

The next operation is to grind it out true again, for the bore is almost certain to have warped a trifle in hardening. The grinding is performed by a lap in a manner to be described in remarks upon laps and lapping. The lapping being completed, the handle may be fitted to the tube, and the cutting edge ground on a grindstone, taking care to only grind sufficient off the bevelled edge to sharpen it, and revolving the cutter so that it will be ground evenly and smooth. The cutting edge should stand at a right angle to the bore, and may be gauged by applying a square to the outside and across the cutting edges of the cutter. The grinding completed, the oilstone may be applied, when the cutter will be ready for use; Fig. 47

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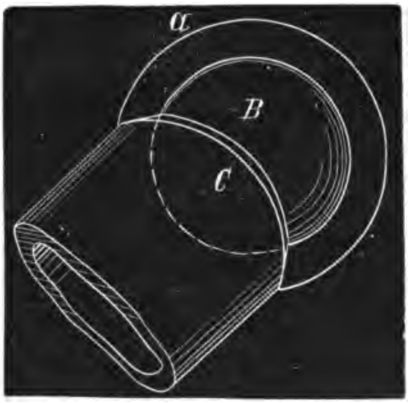
showing the manner of its application, *a* being the chuck, B the ball, and C the cutter.

The cutter, when forced by hand against the revolving ball, trues it up exceedingly smooth and true; the ball being reversed, the operation is repeated in all directions in the chuck, which may be done without stopping the lathe, and then continued until the ball is true, which may be readily known, because the cutter will cut the high parts of the ball easily, taking off large shavings; but

Fig. 47.



when the cutter edge bears equally at all parts on the ball, it will scarcely do more than polish it. When the ball is nearly finished, but a slight pressure must be placed upon the cutter, and the ball must be more frequently reversed in the chuck.

When such balls are used for valves the seat should be turned last, and the ball should be ground to the seat with burnt sand and water.

When bolts and plates are employed to hold rough work, care must be taken to place the plates over those parts of the work which touch against the chuck or face

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plate against which the work is bolted; or the pressure of the plates on the work will spring it, and when it is taken out of the lathe (or other machine) it will spring back to its original position, and the part which has been cut will be no longer true, causing in many cases a great deal of unnecessary vise work. If it is not practicable to so place the plates, then those parts of the work which stand off from the face plate or chuck should be kept from springing by having wedges driven between them and the plate, which is of great importance in light work.

The plates (or clamps) should be so placed that the ends gripping the work travel in advance, the bolts being kept as close to the work as possible and the packing at the other end of the plates. Heavy cast-iron work, requiring much turning to be done to it between the centres should have wrought-iron plugs screwed in the ends, and the centres put into the wrought-iron; because centres, if of cast-iron, cut, and soon run out of truth. Before boring or turning work that is chucked, if there is sufficient room, put a rod of iron between the centres to counteract any end play there may be in the spindle of the lathe. In applying a steady rest, be careful not to put an unequal strain on the work by screwing any of the jaws tighter than the others, or it will spring the work out of the straight line, in which case the cut taken by the tool will not be parallel. When there is sufficient room, use a boring bar with a small tool in it for boring holes; for the extra strength of the boring bar enables the tool to take a heavy cut, which a boring tool having a slight body would not do in consequence of the springing.

If work chucked in a lathe is much heavier on one side than on the other, bolt a weight on the chuck (near the light side of the work) sufficiently heavy to counterbalance it, otherwise the centrifugal force generated by the revolutions of the heavy side of the work will cause it to revolve eccentrically, and to be in consequence turned untrue.

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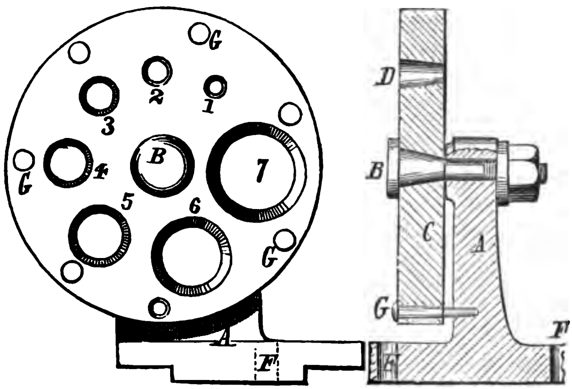
CONE PLATE FOR BORING IN THE LATHE.

For chucking shafts and other similar work in the lathe (to bore holes in the ends of the shafts, etc.), the cone plate shown in Fig. 48 is the best appliance known to machinists. A is a standard, fitting in the shears of the lathe, at E, and holding the circular plate C, by means of the bolt B, which should be made to just clamp the plate C tightly when the nut is screwed tight. The plate contains a series of conical holes, 1, 2, 3, etc. (shown in section

Fig. 48.



at D). The object of coning the pin B, where it carries the plate C, is that the latter shall be made to a good working fit and have no play. The operation is to place the shaft in the lathe, one end being provided with a driver, dog, or carrier, and placed on the running or line centre of the lathe; and the other end, to be operated upon, being placed in such one of the conical holes of the plate C as is of suitable size, the distance of the standard A from the lathe centre is to be adjusted so that the work will revolve in the coned hole with about as much friction as it would have were it placed between both the lathe centres. Thus

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the conical hole will take the place of the dead centre of the lathe, leaving the end of the shaft free to be operated on. FF are holes to bolt the standard A to the lathe shears or bed; and GG, etc., are taper holes to receive the pin G, shown in the sectional view. The object of these holes and pin is to adjust the conical holes so that they will stand dead true with the lathe centres; for if they stood otherwise, the holes would not be bored straight in the work. In Fig. 48, hole No. 7 is shown in position to operate, the pin G locking the plate C in that position. In setting the work, the nut on the pin B should be eased back just sufficiently to allow the plate C to revolve by hand; the work should then be put into position, and the pin G put into place; the standard A should then be adjusted to its distance from the live lathe centre, and bolted to the lathe bed; and finally, the nut on the pin B should be screwed up tight, when the work will be held true, and the cone plate prevented from springing. Care must be taken to supply the conical holes, in which the work revolves, with a liberal quantity of oil, otherwise they will be apt to abrade.

TO TURN A PULLEY.

Chuck the pulley by the arms if it is a large one and true up with a turning tool the outer end of the hole sufficiently to put in a flat drill having wood screwed to its sides as shown in Fig. 2. If only one pulley is to be turned so that it will not pay to make a special drill, use any that may be at hand that is sufficiently large to clean out the hole (which it will do better and more quickly than a boring tool), and then finish the hole with a boring tool. All holes in pulleys which are to be turned in the hole and on the outside at one chucking, as large and heavy pulleys are, should have the hole finished with a boring tool, so as to insure its being true.

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To turn a small pulley bore the hole as above directed, and then drive the pulley on a mandril, and turn the outside of the pulley on the lathe centres. Let the pulley be near the end of the mandril so that it may, when in the lathe, be driven by two driving bolts or studs, which should touch arms as near as possible on opposite sides of the pulley.

All pulleys should be set true with the inside of the rim, which will make them balanced when the outside of the rim is turned up.

Small pulleys or those light in the arms will spring from being chucked by the arms or rim, and, even in the stoutest, great care must be taken to support the arms behind the clamps, or the outside faces of the pulley will not run true, even though the hole was bored and the face turned at one and the same chucking.

In very heavy pulleys, or fly wheels, it is the most easy and convenient to chuck and set true one-half of the wheel first, and to then place on the other half, bolting it first to its mate and then to the chuck plate.

The smoother a pulley is turned the better a belt will hold upon and drive it.

A pulley which is of larger diameter in the middle of its width will not only keep the belt running more true but will make it last longer, because there will be more tension on the middle of the belt than on the edges of it, and the belt is stronger in the middle than on the sides, because the middle is supported by the sides. A pulley covered with leather will transmit thirty per cent. more power, without slipping, than one not so covered.

The alteration of form which takes place in a piece of either cast or forged metal during and after its manipulation, is sufficient in degree to be appreciable in even small work, so that it is a well-understood fact that, on all work in which it is convenient to do so, all parts should be roughed out by having the surface removed by a roughing

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cut before any one part is finished, otherwise the work will not, when finished, be true.

The causes of this alteration of form are, in the case of castings, due partly to the tension which takes place on the whole exterior of the casting during the process of cooling, and partly from the excess of tension which takes place upon those parts of the casting which are the longest in cooling. The difference in the time required to cool a casting depends upon the relative thickness of one part as compared to another, the freedom of access to the air, and the position in which the casting lies while losing its heat, nor is it practicable to so cool a casting as to make its surface-tension equal all over. If a casting is allowed to cool off in the sand, its surface-tension will be less than if extracted from the mould and permitted to cool in the open air, while, if after the casting has become cold, it is reheated to a low red heat, the tension referred to will be considerably reduced, though not altogether removed. To thus reheat large castings is, however, impracticable, and they should be left to cool in the mould, while those extracted from the moulds while hot should be put in some convenient place in the foundry and covered with sand.

In addition to the above tension, many pieces of work are sprung by the pressure of the clamps by which they are fastened (in machines) to be operated on, and in all work of a delicate nature and requiring to be very true, this fact is recognized, and extra feet or chucking-pieces are provided whereby to chuck the work. In stouter work, however, the thickness or strength of the metal is often relied upon as sufficient to withstand the pressure due to the holding clamps, unmindful of the fact that a piece of metal, no matter how thick it may be, will deflect from its own weight, and the result is work which, though cut true while in the machine, is no longer true when taken out of it.

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Then again, the alteration of form due to the removal of the tension on certain surfaces of a piece of work is oftentimes entirely ignored in the order in which the various surfaces are operated upon and removed. Thus in the case of engine-cylinders. The bore is roughed out, and very often finished before the end faces for the cylinder-covers are operated upon, whereas both should be roughed out before either is finished. And it is almost a universal practice to finish the bore and end faces of a cylinder before the flanges which bed to the frame, and before the slide-valve and steam-chest seat faces are planed. Now, the bore of a cylinder should, of all other parts, be when finished true, because, independent of the question of steam economy, it being the longest working surface, a want of truth will be more appreciably felt in it than in any other part; thus supposing the valve-face was out of true to an amount equal to $\frac{1}{32}$ inch in the length of the cylinder, it would be scarcely practically appreciable in the length of its face. Or suppose the face to receive the steam-chest was $\frac{1}{32}$ out of true in the length of the cylinder, the consequences would not be very material, besides which the error would be very easily remediable. Not so, however, with the bore of the cylinder—that would have to pass as it was or be re-bored. The alteration in form takes place in the order in which the tension is removed, so that the last surface operated upon is invariably the most true one. It is obvious, then, that were all the planing done to a cylinder before the boring was performed, the bore would be much truer than under the present system, because the tension on the whole of the surfaces which are intended to be cut off will have been removed previous to taking the finishing cut through the bore.

That the alteration in the bore of cylinders is appreciably experienced is evidenced by the fact that many engine-builders leave the tool-marks plainly sensible both

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to the eye and the touch, claiming that after a little working the piston will fit more true and closely to the cylinder than it would were the cylinder bore quite smooth. And in cases in which much planing has been done to the cylinders after being bored, this is undoubtedly the case, because the wearing surface on the bore of the cylinder is reduced, and hence the tight places or spots wear off more rapidly. Now, let us take the case of slide-valves, which, being of awkward shape to hold, are very apt to spring in the chucking; this part of the subject, however, it is not our purpose to discuss; hence to proceed.

There are two methods adopted to get up slide-valves —one being to get them up to a surface-plate, and the other being to place them so that the tool-marks will be plainly discernible to both the eye and the sense of touch, and to let the planing-marks on the face of the valve run in such a direction that when the valve is upon its seat in the cylinder, the planing-marks on the valve will run at right angles to the planing-marks on the face of the seat. The advocates of this plan claim that after the engine has run a short time, the valve will be a better fit than if both the valve and the seat had been surfaced to a surface-plate; and this is no doubt true in all cases in which, either from excessive inequality in the cooling or from an unusually large amount of metal having been taken off the face of the valve, the tension is considerably removed; for in such case, as soon as the valve becomes heated by the steam, it rearranges its form to suit the altered conditions of the strains upon its surfaces; and here, again, the wearing surfaces being reduced in consequence of the tops only of the planer-marks bearing, those tops will wear rapidly away and let the valve down to a bearing all over quicker than would be the case if the surfaces being smooth there was a greater amount of wearing surface confined within an equal amount of diametrical area. On the other hand, it is undoubtedly true that a valve should

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from the first bed all over its surface, so as to present a smooth and even wearing surface and to be steam-tight. This, however, cannot be insured by simply scraping the two surfaces, and the proper course lies in first planing up the valve wherever it is necessary, and in then reheating it to about the temperature of the steam under which it is to operate, so that the reformation (of the valve) due to the tension on the planed surfaces having been removed, will take place before the face of the valve has been surfaced to the surface-plate. It is sufficient for ordinary practice to place the valve in boiling water, but if great exactness is required, it should be heated to the temperature of the steam under which it is to operate; and in this latter case, another element must be considered, which is, that the inequality of the amount of surface on the face as compared to the back of the valve, and the consequent inequality of the expansion of the valve, due to its being heated, renders it a still more perfect process to heat the valve to its working temperature every time it is, during the process of fitting to its seat, tried upon its seat-surface.

There is probably, however, no instance in which the tension referred to is so sensibly experienced nor so expensive to rectify as in the case of piston-rings. The usual method of making these rings is to cast a ring deep enough to cut the required number out of, and to cast feet on one end of it whereby to chuck it without springing it out of round. In a majority of cases the internal surface or bore of the ring is not trued up in the lathe; the outside being turned true and the end face being trued, each ring is cut off, thus having three turned and true surfaces. So soon as the ring is split, however, as it requires to be, it springs out of true, the result being a tedious and expensive amount of filing and scraping to bring the sides of the ring fair and true again. In rings having the back thicker than the side where the split is placed, so that, in

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springing, the ends will spring more readily and allow the sides of the ring at and near the split to fit more easily and uniformly to the cylinder, the spring sideways and out of true after splitting the ring is generally experienced to a greater degree, owing to one side of the ring cooling more readily than the other. The remedy in both cases is to bore out the inside as well as turning the outside of the ring, and to take about as much metal off the inside as off the outside, for even that will make a difference, and in very large rings it will pay to light a wood-fire around them and re-heat them, letting them cool off in the embers, and covering them with sawdust and sand mixed, added after the rings are barely red-hot, placing a slightly thicker layer on the thin side of the ring. In forgings, the same surface-tension takes place, the alteration of forms being less, it is true, but nevertheless appreciable. In this case, however, there is no doubt but that it is more the working of the metal at different temperatures and to a varying degree which is the cause, than is the unequal cooling of the surface of the forging. It is impossible for a blacksmith to keep this work at an even temperature all over, or to deliver the blows equal in force to all parts of the job; while the metal worked the coldest has the greater tension on it, and that receiving the heavier blows has, supposing the temperature to be equal, the greater tension on it. The effects upon forgings may be instanced in several ways; for example, if a tap is forged, heated to a red heat, and allowed to cool, and is afterwards turned, it will in all probability warp in the hardening, unless it is heated after the outer skin has been burned off it all over—that is, after the tap has been completely roughed out. The centres of a lathe may be turned up as true as possible, the work may be centre-drilled, the ends trued up and properly countersunk, the work may be run a considerable time in the lathe at a fast speed, and turned end for end so as to insure that the centres of the work have

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become properly bedded to those of the lathe, and yet if the work, say a piston-rod, be turned up half its length, and then, after being reversed in the lathe, the other half be turned up, the one half will not be true with the other. In fact, under the most careful manipulation and with the best of tools, we cannot bore and turn even a common double eye and single eye, and make the two fit evenly and fair one with the other, so that the bolt shall pass through, a good fit in both without springing either, and we are compelled, after fitting the double eye, to take a hand reamer and pass through the hole while the two are together to make a practically perfect fit. We may take an eccentric strap, put together in two halves, properly surfaced and fitted together, and composed either of wrought-iron, cast-iron, or brass, and under ordinary careful and commercially practicable manipulation, we cannot bore such a strap to either fit a cylinder of its size, or so that the two halves shall be equal in diameter across the joint when taken apart. Properly conducted experiments would probably show that in many instances, such, for instance, as in the case of locomotive slide-valves, a practical difference would be found in the manner of cooling the valve after being cast, for if the wearing face be uppermost, the crystals of the iron will lie at right angles to it, since the crystals lie lengthwise in the direction in which the heat passes off, and though the heat will pass off from all the surfaces, yet it will pass off most readily from the surfaces most exposed or most readily cooled, and it is as yet an unsolved problem as to what alteration in the crystal formation of the iron may be induced by either variations in the conditions or relative rapidity of cooling the various surfaces, as, for example, by revolving castings in the mould during the process of cooling, or by retaining the heat somewhat on one side only; and also what effect the direction in which the crystals of cast-iron lie has upon the tension of the out-

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side or surface skin and upon the wearing qualifications of the metal. Some slide-valves will cut, though faced and refaced, while a new valve will be found to work admirably. Now, whether the difference lay in the fact that the one cooled standing edgewise and the other with the face up or down, or whether such condition of cooling, affecting, as it does, the direction in which the crystals lie, also affects the wearing or abrading qualifications of the metal, experiment alone can determine.

TURNING AND FITTING TAPERS.

In turning tapers in the lathe, it is impracticable to set the lathe correct by measuring the amount of set over given to the tail stock of the lathe, nor is there any practicable method of setting the lathe to the exact required taper, without trying and fitting the work, the reasons being as follows:

Supposing the tail stock to be provided with a scale whereby to measure the amount to which it is set over; it then becomes necessary to countersink the work to exactly the same depth, so that the lathe centres will always fit it to an equal depth, otherwise the truth of the sliding scale will be destroyed. Then, again, supposing the work to be so correctly countersunk, it will still be useless, as the lathe centres will enter the work deeper as the turning proceeds. Even, however, were such not the case, it would be impracticable to set correct tapers from the tail stock, because, in a majority of cases, the tapers upon work do not run from end to end of the work, and it will take less time to set the taper by more simple means than it will to perform the necessary calculations; especially is this the case because of the trouble entailed in ascertaining the exact distance to which the lathe centres enter the work, which distance varies, because of the excessive wear in the centre of the work which takes place in turning tapers by setting over the tail stock. The reason of

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this excessive wear is, that the tail stock of the lathe, when set over, stands parallel with the centre line of thè length of the lathe shears, while the centre line of the work, when placed between the lathe centres, does not stand parallel with those shears, so that the lathe centres do not stand true in the work centres, thus causing excessive pressure and abrasion on the centres of both the lathe and the work. If we notice the dog fastened to a piece of work placed in the lathe and revolved, while the tail stock of the lathe is set over, we shall find that the head of the dog recedes from the face plate of the lathe during one half, and approaches it during the other half, of each revolution, showing that the dog, and hence the work, is not revolving in the same plane as is the face plate of the lathe. As a consequence, each centre of the lathe is on one side bearing on the outer diameter of the cone of the centre in the work, while on the other side it is bearing on the inner or smaller diameter of the cone or countersink of the centre in the work.

In soft metals the wear (from the above causes) of the work centres being excessive, the work is very apt to become untrue and to keep varying in its centres, rendering it very difficult to finish it true. So also in cast-iron work, which abrades very easily upon the lathe centres, the work is apt to become untrue. Wrought-iron does not suffer so much unless it is seamy, or there are soft or hard spots or parts in the metal, in which case it is impossible to keep it true. In steel work but little difficulty is experienced because the homogeneity and texture are sufficiently even and close to resist the tendency to abrasion. There is, however, in the case of any metal another thing to be considered, which is that no work can be turned true in the lathe unless all the surfaces requiring to be turned up are roughed out, before any one part is finished, as has already been explained in another place. So that in turning up a piece of work having a plain and a

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taper part, we are confronted with the following considerations:

If we turn up and finish the plain part first, the removal of the skin, and the wear to the centres during the operation of turning the taper part, will cause the work to run out of true, and hence it will not, when finished, be true; or if, on the other hand, we turn up the taper part first, the same effect will be experienced in afterwards turning the plain part. We may, it is true, first rough out the plain part, then rough out the taper part, and then finish first the one and then the other; to do this, however, we shall require to set the lathe twice for the taper and once for the parallel part, the latter for long parallels being a long and tedious operation, especially if the tail stock has no accurate scale or line whereby to denote when it is set parallel, while even if it has, it is scarcely practicable to set it dead true on the first trial, hence it becomes necessary to take a fine trial cut, entailing, therefore, that much extra labor.

The tail stocks of lathes designed to turn tapers by having the tail stock set over should be provided with a taper pin hole and pin, the one neatly fitted to, and ground into the other, and located so that the tail stock will be in position to turn parallel when the pin is driven lightly home. It is found in practice that the work will be more true by turning the taper part the last, because the work will alter less upon the lathe centres when changed from parallel to taper turning, than when changed from the latter to the former. In cases, however, in which the parts fitting the taper part require turning, it is better to finish the parallel part last and then turn up the work fastened to the taper while it is fast upon its place; thus, in the case of a piston-rod and piston, were we to turn up the parallel part of the rod first, and the taper last, and the centres altered during the last operation, when the piston head was fastened on the rod, and the latter was

placed in the lathe, the plain part of the rod would not run true, and we should require to true the centres, to make the rod run true, before turning up the piston head. If however, we first rough out the plain part or stem of the rod and then rough out and finish the taper part, we may then fasten the piston head to its place on the rod, and turn the two together; that is to say, rough out the piston head, then finish the rod, and subsequently the head; thus will the head and rod be true together, whether the taper is true with the parallel part of the rod or not. The easiest way to set a lathe tail stock for a required taper is as follows: If we have a pattern we may place the same in the lathe centres, and fasten a tool in the lathe tool post and set over the tail stock until the point of the tool, moved along with the slide rest, will just touch the taper of the pattern evenly from end to end.

If we have no pattern we may turn the part requiring to be taper parallel at each end, leaving it say $\frac{1}{32}$ inch larger than the required finished size; we then fasten a tool in the lathe tool post. Place it so that it will clear the metal of the part requiring to be turned taper, and placing it at one extreme end of said part, we take a wedge and insert it between the turned part of the work and the tool point sufficiently tightly to cause the tool point to mark the wedge. Taking the wedge out, we wind the slide rest along until the tool point stands at exactly the other end of the taper part of the work, and, inserting the wedge, we note how far the wedge will enter between the work and the tool point, it being obvious that when the wedge will enter to an equal distance or thickness at each end of the taper part, the lathe is set. It is usually, however, necessary to try the cone after the first and second cuts to adjust the lathe to exactness.

Lathes having compound slide rests (in which case the top slide of the rest may be set to the required taper without the tail stock being moved) may be set with the tool

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tried with the pattern, or the wedge, under the same conditions as the above. In the case of having a pattern, however, it will save a little time to place the pattern between the lathe centres and move the top slide of the rest by hand until the eye, levelled so as to bring the outline of the tapers and the edge of the top slide close together, judges the one to be parallel with the other. Hand slide rests may be set in like manner, and, when the latter requires to be set parallel, they may be adjusted nearly true by bringing the edge of the slide rest slide parallel with the edge of the lathe bed, or with the edge of the raised V slides of the lathe bed.

To try a taper into its place, we either make a chalk stripe along it, smoothing the chalked surface with the finger, or else apply red marking to it, and then while pressing it firmly into its place, revolve it back and forth. Then, while holding it firmly to its seat in the hole, we move the longest outwardly projecting end up and down and sideways, noting at which end of the taper there is the most movement; the amount of the movement will denote how far the taper is from fitting the hole, while the end having the least movement will require to have the most taken off it, and the fulcrum off which the movement takes place is the part requiring the most to be taken off.

Having fitted a taper as near as possible with the lathe tool, that is to say, so nearly that we cannot find any movement or unequal movement at the ends of the taper (for there is bound to be movement if the taper hole is rounding in the outline of its length), we must finish it with a smooth file, as follows: First marking the inside of the hole with a very light coat of red marking, and being careful that there is no dirt or grit in it, we press the taper into the hole firmly, holding it to its seat while revolving it back and forth, and still slowly advancing it forward, so that while the movement has been a reciprocating one, it has still been a revolving one, at least two

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complete revolutions of the taper plug in the hole having been made. The work should be run in the lathe at a high speed, and a smooth file used to ease off the marks visible on the taper, applying the file the most to the parts having the darkest appearance, since the darker the marks the harder the bearing has been. Too much care in trying the taper to its hole cannot be taken, since it is apt to mark itself in the hole, even though it does not fit accurately; that is to say, to mark itself as though it did fit in places where it does not fit. It is necessary, therefore, at each insertion, to minutely examine the movement up and down and sideways above referred to.

A taper or cone should be fitted to great exactitude before it is attempted to grind it, the latter process being merely intended to make the surfaces even. For wrought-iron, cast-iron or steel work, oil and emery are used for the grinding material. The emery should be rubbed evenly with the finger over the surface of the hole and the plug or taper, which latter should be placed carefully in its place and forced firmly to its seat, while it is revolved back and forth, and slowly rotated forward by moving it farther during the forward than during the backward movement of the reciprocating motion. After about every dozen strokes the plug cone should be removed from the hole, and the emery again spread evenly over the surface with the finger, and at or during about every third one of the back strokes of the reciprocating movement the taper should be slightly lifted from its bed in the hole, being pressed tightly home on the return stroke, which procedure tends to spread the emery and make the grinding smooth and even. The emery used should be about number 60 to 70 for large work, about 80 to 100 for small, and flour emery for very fine work.

Any attempt to grind work by revolving it in one direction will cause it to cut or abrade, thus destroying the smooth surface.

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BELTS.

All belts should be run with the grain or smooth side to the pulley, which will transmit 30 per cent. more power than will the same belt with the flesh side to the pulley.

OILING AND GREASING OF BELTS.

Care should be taken that belts are kept soft and pliable.

When the belt is pliable, and only dry and husky, blood-warm tallow should be applied; this applied and dried in by heat of the fire or sun, will tend to keep the leather in good working condition; the oil of the tallow passes into the fibre of the leather, serving to soften it, and the stearin is left on the outside to fill the pores and leave a smooth surface. The addition of resin to the tallow, for belts used in wet, damp places, will be of service, and help preserve their strength. Belts which have become hard and dry should have an application of neat's foot or liver oil mixed with a small quantity of resin; this prevents the oil from injuring the belt and helps to preserve it. There should not be so much resin as to leave the belt sticky.

DIRECTIONS for calculating the width of Belts required for transmitting different numbers of horse-power.

The following calculations were predicated on the basis of allowing each square inch of belting in contact with the drum or pulley to raise half a pound one foot high in one minute, and the raising of 36,000 pounds same height in same time as a horse-power.

By increasing the tension of the belt more than a half may be allowed to the square inch.

Multiply 36,000 by the number of horse-power; divide the product by the number of feet the belt is to run per minute; divide the quotient by the number of feet or parts of a foot in length of belt contact with the smaller drum

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or pulley; divide this last quotient by 6, and the result is the required width of the belt in inches.

DIRECTIONS for calculating the number of horse-power which a belt will transmit, its velocity and the number of square inches in contact with the smallest pulley being known.

Divide the number of square inches of belt in contact with the pulley by 2; multiply this quotient by the velocity of the belt in feet per minute, and this amount divided by 36,000, and the quotient is the number of horse-power.

When belts are run horizontally, the lower half should be the driving half when practicable; then, as it stretches, the loose or upper half will cover more and more of the pulley surface. If run the other way, then, as the band stretches, it will fall from the pulleys, having less of contact surface.

Long horizontal belts are so far desirable, as that their weight increases their contact with the pulley. Double bands have this advantage to a great extent.

Belts connecting pulleys perpendicular to each other should be kept tightly strained, and should be of well-stretched leather, as their weight tends to decrease their close contact with the lower pulley.

Belts of coarse, loose leather, will do better service in dry, warm places than in wet or moist. For use in these last named places, bands should be made of the *finest* and *firmest* leather.

If in lacing a belt, the ends, if a butt joint, or the lap, if a lap joint, are not cut in the one case, and laced in the other case, square, so as to keep the edges straight, the side of the belt that is hollow, and which is of course the tightest, will stretch and tear, and the belt will run off the pulley or drum on that side.

A single belt will in a short or narrow belt, or in such

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a belt as is in ordinary use in a machine shop, work better in every respect than a double one, and is far easier to shift from one step to another of a cone pulley.

To find the length of a required belt add together the diameter of the two pulleys, divide the total by 2, and multiply the quotient by $3\frac{1}{4}$; then to the last product add twice the distance between the centres of the shafts, and the sum will be the length of the belt required.

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CHAPTER VII.

HAND-TURNING.

Turning work in the lathe with a tool held or guided by hand, or, as it is commonly termed, hand-turning, is at once one of the most delicate and instructive branches of the machinist's art, imparting a knowledge of the nature and quantity of the resistance of metals to being cut, of the qualifications of various forms of cutting tools, and of the changes made in those qualifications consequent upon the relative position or angle of the cutting edge of the tool to the work; and this knowledge is to be obtained in no other way than by the practice of hand-turning.

It is the work of an instant only to vary the relative height and angle of a hand tool to the work, converting it from a roughing to a finishing tool or even to a scraper, which operations are difficult and sometimes impracticable, if not impossible, of accomplishment with a tool held in a slide rest.

The experience gained from the use of slide rest tools is imparted mainly through the medium of the eyesight, whereas in the case of a hand tool the sense of feeling becomes an active agent in imparting, at one and the same time, a knowledge of the nature of the work and the tool; so much so, indeed, that an excess in any of the requisite qualifications of a hand tool may be readily perceived from the sense of feeling, irrespective of any assistance from the eye; and in this fact lies the chief value of the experience gained by learning to turn by hand.

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For instance, there is no method known to practice whereby to ascertain how much power it requires to force a slide rest tool into its cut, or to prevent its ripping in; so that a wide variation, in the tendency of such a tool to perform its allotted duty easily and without an unnecessary expenditure of power, may exist without becoming manifest to any save the experienced workman; whereas the amount of power required to keep the cutting edge of a hard tool to its work, to hold it steadily, or to prevent it from ripping, is communicated instantly to the understanding through the medium of the sense of feeling. Nor is this all, for even the sense of smell becomes a valuable assistant to the hand-turner. Several metals, especially wrought-iron, steel and brass, emit (when cut at a high speed) a peculiar smell, which becomes stronger with the increase in the speed at which they are cut and the comparative dulness of the edge of the tool employed to cut them, more especially when the cutting edge of the tool is supplied with oil during the operation of cutting. The reason that this sense of smell becomes more appreciable during the operation of hand than during that of slide rest turning, is because the face of the operator is nearer to the work, and because hand-turning is performed at a higher rate of cutting speed.

If a tool for use in a slide rest is too keen for its allotted duty, the only result under ordinary circumstances is, that it will jar or chatter (that is, tremble and cut numerous indentations in the work), or that it will loose its cutting edge unnecessarily soon. But a hand tool possessing this defect will in many instances rip into the work, because the power, required to prevent the strain, placed by the cut upon the tool, from forcing the tool deeper into its cut than is intended, is too great to be sustained by the hand; and the tool, getting beyond the manipulator's control, rips into the work, cutting a gap or groove in it, and perhaps forcing it from between the centres of the

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lathe. If, on the other hand, a tool is of such a form that it requires a pressure to keep it to its duty, the amount of such pressure, when the tool is held at any relative height and angle to the horizontal centre line of the work, and the variation in that amount, due to the slightest alteration of the shape of the tool, are readily appreciated by sensitiveness of the hand; when they would be scarcely, if at all, perceived were the same tool, under like conditions, used in a slide rest.

These considerations, together with the great advantage in the relative rapidity with which the form and applied position of a hand tool may be varied, render hand-turning far more instructive to a beginner than any other branch of the machinist's art.

It is a common practice to centre one end of the work only, and to fasten the other end in a chuck, thus making the chuck serve as a driver, and obviating the necessity of centre-punching more than one end of the work. This method will, it is true, save a little time, but is objectionable for the following reasons: Chucks will run quite true while they are new, and indeed for some little time, but they do in time get out of true; and as a result, if the work requires to be reversed in the lathe so as to be turned from end to end, the part of the work turned during the second chucking will be eccentric to that part turned during the first chucking. If one end only of the work requires to be turned, and needs be true only of itself, and irrespective of the part held in the chuck, the latter may be employed; this subject will, however, be treated hereafter.

Our first operation, that is, truing the end of the work, is performed with a side tool, of which there are two kinds, both being made of three-cornered (or three-square, as it is generally termed) steel, the only point of difference being in the manner of grinding them. A worn-out saw file is an excellent thing to make a side tool of, because

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the teeth grip the rest and prevent the tool from slipping. It is not necessary to soften the file at all, but (for either kind) merely to grind it so as to make one edge a cutting one, and not make the point too thin, by grinding the end off a trifle.

If the cutting edges are smoothed by the application of an oilstone, they will give a very clean and smooth polish to the work. The rest should be set at such a height that the cutting edge of the tool is slightly above the horizontal centre of the work; and the tool should be so held that its side face stands nearly parallel with the end face of the work, the cutting edge being held slightly inclined towards the work, which will give to the tool edge the necessary clearance. Any excess of this inclination renders the tool liable to turn out of true, and destroys its cutting edge very rapidly.

ROUGHING OUT.

Our work, being countersunk, is now ready to be turned down to nearly the required size all over, before any one part is made to the finished size.

From what has been said in another place, the importance (in work which requires to be kept very true) of roughing the work out all over before any one part is finished will be obvious, since the breaking of the skin in any one part releases the tension on that part, whatever be the temperature it is under when in operation. It is not practicable, on lathe work, to at all times rough the work out all over before finishing any part; but in our present operation, of turning down a plain piece of iron held between the lathe centres, we are enabled to pursue that course, and we will therefore commence the roughing-out process with a graver.

THE GRAVER

is formed by grinding the end of a piece of square steel at an angle across the end, giving it a diamond-shaped appearance.

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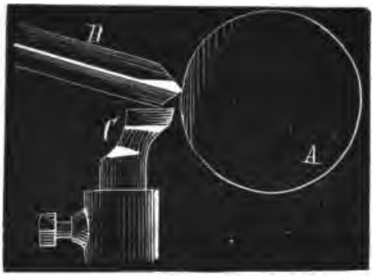
The graver is the most useful of all hand tools used upon metals. It can be applied to either rough out or finish steel, wrought-iron, cast-iron, brass, copper or other metal, and will turn work to almost any desired shape. Held with a heel pressed firmly against the hand rest (the point being used to cut, as shown in Fig 49, A being the work, B the graver, and C the lathe rest), it turns very true, and cuts easily and freely. This, therefore, is the position in which the graver is held to rough out the work.

Fig. 49.



The heel of the graver, which rests upon the hand rest, should be pressed firmly to the rest, so as to serve as a fulcrum and at the same time as a pivotal point upon which it may turn to follow up the cut as it proceeds. The cutting point of the graver is held at first as much as convenient toward the dead centre, the handle in which the graver is fixed being held lightly by both hands, and slightly revolved from the right towards the left, at the same time that the handle is moved bodily from the left towards the right. By this combination of the two movements, if properly performed, the point of the graver will move in a line parallel to the centres of the lathe, because, while the twisting of the graver handle causes the graver point to move away from the centre of the diameter of the work, the moving of the handle bodily from

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left to right causes the point of the graver to approach the centre of that diameter; hence the one movement counteracts the other, producing a parallel movement, and at the same time enables the graver point to follow up the cut, using the heel as a pivotal fulcrum, and hence obviating the necessity of an inconveniently frequent moving of the heel of the tool along the rest. The most desirable range of these two movements will be very readily observed by the operator, because an excess in either of them destroys the efficacy of the heel of the graver as a fulcrum, and gives it less power to cut, and the operator has less control of the tool.

The handle in which the graver is held should be sufficiently long to enable the operator to grasp it with both hands and thus to hold it steadily, even though the work may run very much out of true.

To cut smoothly, as is required in finishing work, the graver is held as shown in Fig. 50, C being the work. The edge on the end of the graver and between the corners, A and B, of the graver, performs the cutting operation.

Fig. 50.

By holding the graver in the positions described, and in various modifications of the same, the work may obviously be turned parallel, with either round edges, curves, or square shoulders, and it is possible to turn almost any shape with this one tool. For finishing curves, however,

the end of the graver (the cutting edge, on the end and between the curves A and B in Fig. 50) should be rounded. Even parallel work should be finished by being filed with a smooth file while the lathe is running at a high speed. As little as possible should, however, be left for the file to do, because it cuts the softer veins of the metal more readily than the rest, and therefore makes the work out of true.

For use on brass and other soft metals, the two top flat sides of the graver should be ground away so as to have a negative top rake. The strain on the tool, when cutting soft metals, is comparatively slight, so that the graver is rarely applied to such metals in the position shown in Fig. 49.

THE HEEL TOOL.

In those exceptional cases in which, want of a lathe having a slide rest, it becomes necessary to perform comparatively heavy work in a hand lathe, the heel tool should be employed. This tool was formerly held in great repute, but has become less useful by reason of the advent and universal application of the slide rest. It is an excellent one for roughing work out, and will take a very heavy cut for a hand tool, because of the great leverage it possesses, by reason of its shape and handle, over the work. A heel tool is shown in Fig. 51, A being the tool, which is a piece of square bar steel forged at the end to form the cutting edge. The body of the square part is held (in a groove formed in the wooden handle B) by an iron strap C, which is tightened by screwing up the under handle D, which contains a nut into which the spindle of the strap C is screwed as the handle D is revolved. The heel F of the tool is tapered, so that it will firmly grip the face of the lathe rest, the cutting edge E being rounded as shown in Fig. 51. The tool is held by grasping the handle B at about the point G, with the left

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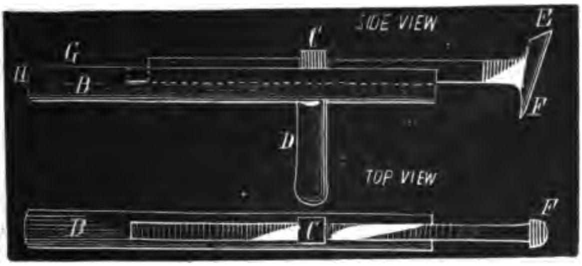
hand, and by holding the under handle D in the right hand, the extreme end H of the handle being placed firmly against the right shoulder of the operator. The heel F of the tool must be placed directly under the part of the work it is intended to turn, the cutting edge E of the tool being kept up to the cut by using the handle D as a lever, and the heel F of the tool as a fulcrum. Not much lateral movement must, however, be allowed to the cutting edge of the tool to make it follow the cut, as it will get completely beyond the manipulator's control and rip into the work. Until some knowledge of the use of this tool has been acquired, it is better not to forge the top of

Fig. 51.



the cutting edge E too high from the body of the tool; since the lower it is the easier the tool is to handle.

The heel tool should, like the graver, be hardened right out; but in dipping it, allow the heel F to be a little the softer by plunging the end E into the water about half way to F; and then, after holding it in that position for about four seconds, immerse the heel F also. After again holding the tool still for about six seconds, withdraw it from the water and hold it until the water has dried off the point E; dip the tool again, and quickly withdraw it, repeating this latter part of the operation until the tool is quite cold. The object of the transient dippings is to pre-

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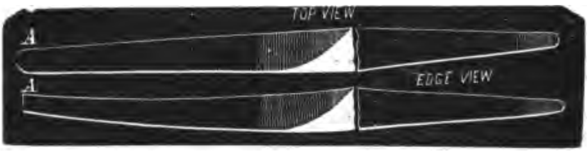
vent the junction of the hard and soft metal from being a narrow strip of metal, in which case the tool is very liable to break at that junction. The tool should be so placed in the handle that there is only sufficient room between the cutting edge and the end of the handle to well clear the lathe rest, and should be so held that the handle stands with the end H raised slightly above a horizontal position, the necessary rake being given by the angle of the top face at E. It is only applicable to wrought-iron and steel; but for use on those metals, especially the latter, it is a superior and valuable hand tool.

For cutting out a round corner, a round-nosed tool of the same description as the V tool given for starting threads by hand, but having the cutting edge ground round instead of a V shape, is the most effective; it will either rough out or finish, and may be used with or without water, but it is always preferable to use water for finishing wrought-iron and steel. This is a sample of a large class, applicable to steel and wrought-iron, the metal behind the cutting edge being ground away so as to give to the latter the keenness or rake necessary to enable it to cut freely, and the metal behind the heel being ground away to enable it to grip the rest firmly.

HAND-TURNING—BRASS WORK.

For roughing out brass work, the best and most universally applicable tool is that shown in Fig. 52, which is to

Fig. 52.



brass work what the graver is to wrought-iron or steel. The cutting point A is round-nosed. The hand rest

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should be set a little above the horizontal centre of the work, and need not be close up to the work, because comparatively little power is required to cut brass and other soft metals, and therefore complete control can be had over the tool, even though its point of contact with the rest be some little distance from its cutting point, which allows a greater range of movement of the tool from a fixed point. The best method of holding and guiding is to place the forefinger of the left hand under the jaw of the hand rest, and to press the tool firmly to the face of the rest by the thumb, regulating the height so that the cutting is performed at or a little below the horizontal centre of the work. The tool point may thus be guided with comparative ease to turn parallel, taper, or round or hollow curves, or any other desirable shape, except it be a square corner. Nor will it require much moving upon the face of the lathe rest, because its point of contact, being somewhat removed from the rest, gives to the tool point a comparatively wide range of movement. The exact requisite distance for the rest to be from the work must, in each case, be determined by the depth of the cut and the degree of hardness of the metal; but as a general rule, it should be as distant as is compatible with a thorough control of the tool. The cutting end of this tool should be tempered to a light straw color.

SCRAPERS.

To finish brass work, various shaped tools, termed scrapers, are employed. The term scraper, however, applies as much to the manner in which the tool is applied to the work as to its shape, since the same tool may, without alteration, be employed either as a scraping or a cutting tool, according to the angle of the top face (that is, the face which meets the shavings or cuttings) to a line drawn from the point of contact of the tool with the work to the centre line of the work, and altogether irrespective of the angles of the two faces of the tool whose

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junction forms the cutting edge. To give, then, the degree of angle necessary to a cutting tool, irrespective of the position in which it is held, is altogether valueless, as will be readily perceived.

Scrapers will cut more freely if applied to the work with the edges as left by the grindstone; but if they are smoothed, after grinding, by the application of an oilstone, they will give to the work a much smoother and higher degree of finish. They should be hardened right out for use on cast-iron, and tempered to a straw color for brass work. If the scraper jars or chatters, as it will sometimes, by reason of its having an excess of angle or bottom rake, or from the cutting end being ground too thin, a piece of leather, placed between the tool and the face of the rest, will obviate the difficulty.

Round or hollow curves may be finished truly and smoothly by simply scraping; but parts that are parallel or straight upon their outer surfaces should, subsequent to the scraping, be lightly filed with a smooth file, the lathe running at a very high speed to prevent the file from cutting the work out of true.. The file should, however, be kept clean of the cuttings by either using a file card or cleaner, or by brushing the hand back and forth on the file, and then striking the latter lightly upon a block of wood or a piece of lead, the latter operation being much the more rapid, and sufficiently effective for all save the very finest of work. If the filings are not cleaned from the file, they are apt to get locked in the file teeth and to cut scratches in the work. To prevent this the file may be rubbed with chalk after every eight or ten strokes, and then cleaned as described. After filing the work, it may be polished with emery paper or emery cloth. The finer the paper and the more worn it is, the better and finer will be the finish it will give to the work; for all metals polish best by being rubbed at a high speed with a thin film composed of fine particles of their own nature, as ivory is

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best polished by ivory powder, and wood by shavings cut from itself. To facilitate obtaining the film of metal upon the emery paper, the latter may be oiled to a very slight extent, by rubbing a greasy rag over it, which will cause the particles it at first cuts to adhere to its surface. Crocus cloth is the best for highly finishing purposes, because it will wear longer without becoming torn. It should be pressed hard against the work, and reversed in all directions upon it, so as to wear all parts of its surface equally, and to distribute the metal film all over; and the work should be revolved at as high a speed as possible, while the crocus cloth, during the first part of the polishing, is kept in rapid motion upon the work backward and forward, so that the marks made upon the work by the emery cloth will cross and recross each other. When fine finishing is to be performed, the crocus cloth should be pressed very lightly against the work and moved laterally very slowly.

Round or hollow corners, or side faces of flanges, of either wrought or cast-iron or brass, may be polished with grain emery and oil, applied to the work on the end of a piece of soft wood, the operation being as follows: The end of the wood to which the oil and emery is to be applied should be slightly disintegrated by being bruised with a hammer; this will permit the oil and emery to enter into and be detained in the wood instead of passing away at the sides, as it otherwise would do, thus saving a large proportionate amount of material. The wood, being bruised, will also conform itself much more readily to the shape of curves, grooves, or corners. The hand rest is then placed a short distance from the work, and the piece of wood rests upon it, using it as a fulcrum. The end of the wood should bear upon the work below the horizontal level of the centre of the latter, so that depressing the end of the wood held in the hand employs it as a lever, placing considerable pressure against the work; and the distance

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of the rest from the work allows the end of the piece of wood to have a reasonable range of lateral movement, without being moved upon the face of the lathe rest. The method of using the wood is the same as that employed in using emery cloth, except that it must, during the earlier stage of its application, be kept in very continuous lateral movement, or the grain emery will lodge in any small hollow specks which may exist in the metal, and hence cut small grooves in the work. Another exception is that the finishing must be performed with only such emery as may be embedded in the wood, and without the application of any oil; especially are these directions necessary for cast-iron or brass work. The work may then be wiped dry, and an extra polish imparted to it by the application of fine or worn and glazed emery cloth, moved slowly over its surfaces.

LATHE CHUCKS.

That class of lathe work, which, by reason of its shape, cannot be held and driven between the lathe centres, is what is termed chucked, that is to say, it is fastened to the face plate of the lathe by suitable plates and bolts, or held in special chucks. Of special chucks, the universal chuck is the most useful, and is so common that a description of it is unnecessary. When the running centre of the lathe is removed in order to put a chuck on the spindle, the hole into which the centre fits should be carefully plugged with either rag, cotton waste, or paper, to prevent the metal turnings or dirt from getting into it; and the screw on the lathe spindle and the face of the collar at the end of the screw should all be carefully wiped, as should the face of the hub or boss of the chuck, since the presence of any dirt there will cause the chuck to run out of true. When the chuck is removed from the lathe, it should be put away standing upright and not laid flat upon its face, in which position dust would accumulate in the thread.

If a piece of work requires to be operated upon at a dis-

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tance from the face of the chuck, a universal chuck will not hold it sufficiently firmly; and the bell chuck shown in Fig. 53 should be brought into requisition. In using this chuck it is best to set the work as nearly true as possible, using the front screws A A before attempting to adjust the four back screws, and to set the work true near the front face of the chuck, striking the work with a mallet (on the end standing out farthest from the chuck) to true it; and then, when the work is adjusted as nearly true as possible, to set up the four back screws, until they

Fig. 53.

each bear lightly upon the work, and then tighten them gradually and successively, giving them not more than a quarter turn each at a time, and continuing from one to the other until they are finally screwed sufficiently tight, which proceeding will prevent the springing of the work by the screws. The bell chuck will hold work very firmly, and obviate the necessity (in most cases) of a guide or cone chuck being placed upon the outer end of the work to steady it.

The screws should be made of steel, the ends being turned down below the depth of the threads, so that, if in the course of time the ends should bulge from the pressure of the screws, it will, nevertheless, be an easy matter to

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remove them from the chuck, to replace them when necessary, or to straighten them if they become bent, as is sometimes the case. To prevent bulging, the ends should be tempered to a straw color. When tubes, brass work, or finished work, which is liable to be damaged by the pressure of the screws, is held in a bell chuck, a piece of soft metal, as copper or brass, should be interposed between the screws and the work; and here it is as well to remark that the same precautions should be taken in fastening a carrier, driver, or dog to work driven thereby. Pieces of copper, both flat and of circular form, should be kept for this especial purpose. To hold rings or hollow work larger in diameter than the bell chuck, the screws may be inverted, that is, put into the chuck with the heads inside and the ends protruding outside the chuck; it is, however, at times difficult in such cases to obtain access to the heads of the screws, but whenever this can be done, the bell chuck will be found a most effective and serviceable tool. A special implement should be kept for inserting into the holes of the heads; for if promiscuous pieces of steel are used, they will destroy the screws by bulging outwards the edges of the holes, making them taper, and causing the lever to slip outwards and away from the screw head. Such an implement is called a "Tommy," and it is made of round cast-steel and left soft, the sizes of the ends being made to fit the holes in the screw heads. One end should be bent to an angle of about 45° to enable it to be used in instances when the other end could not be employed, by reason of some obstruction or interposing projection upon the work.

The next form of chuck to be considered is the dog chuck; and of this there are two kinds, the first being one in which the screwing inwards or outwards of one dog operates one or more of the others, by means of gearing or other suitable devices, and the second being those in which the dogs slide in grooves or slots in the chuck plate, and are

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adjusted to accommodate the work, and then bolted firmly to the chuck plate, the work being held by screws passing through the jaws of the chuck.

The first kind of chuck is a very useful tool for ordinary work, and is a necessity to every lathe; but however well it may be made, and no matter how carefully it is used, it will become in time out of true and unfit for work requiring great nicety. For work which does not require reversing in the chuck, it is of course at all times good; but if the work does require reversing, the jaws of the chuck will require adjustment to keep them true; and since such jaws are hardened, they cannot be turned up in their places unless they are first removed from the chuck and softened. There can be no doubt that, in a majority of cases, ill usage causes these chucks to get out of true rapidly; and a common reason for their depreciation arises from the following causes: The jaws are, of necessity, adjusted to fit the slots or grooves in the chuck plate with great exactitude, and it will be readily understood that the presence of any dirt upon the face plate will make it very difficult to move the jaw either towards or away from the centre of the chuck, and that even the absence of sufficiently frequent lubrication will produce the same effect, because the dust and fine particles of metal collect upon and in the grooves of the chuck, and form a species of gum coating, not unlike india rubber, forming a serious obstacle to the movement of the jaw. Instead of properly cleaning the chuck, to obviate the difficulty, the artisan, especially if his job is in a hurry, is apt to slack back the nut, thus causing the jaw to fit loosely to the thickness of the chuck plate, so that when the jaw is forced against the work, it springs away from the face of the plate in the direction shown in Fig. 54, the amount to which the nut is loosened determining the degree to which the lower end of the jaw will spring away from the chuck plate in cases where the work is being held by the inside face E of the chuck.

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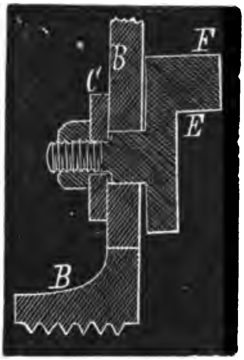
If, however, the outside face F of the jaw is gripping the work, the jaw will spring in the opposite direction, so that the lower end of the jaw (shown in Fig. 54 to be away from the chuck) will be close to it, and the outer end will spring off, the conditions of pressure being exactly reversed. It will be at once perceived that the wear of the face of the jaw and of the face of the plate C, which fits against the face plate B, will, if not taken up by the nut, produce in time the same defect; and it is this wear, together with that of the screws, nuts, and gearing, if there be any, to operate the screws, which causes this class of chuck to get out of true, even if carefully used.

Fig. 54.



Many cases arise in which it is necessary that the inside face of a piece of work requires when chucked to bear against the face plate if the jaws grip at F, and against the face of the jaw if the jaws grip the work at E, so as to insure the work being set true with that face. When, however, the jaws of the chuck are loose in the slots or slides, as shown in Fig. 54, tightening the jaws upon the work will force the latter away from the face plate to an amount proportionate to a degree of looseness of the jaw, the effect being to spring or force the work away from the face of the chuck, rendering it very troublesome to set the work true, and entailing a great loss of time; for a very slight defect in a chuck is, by reason of reversing the work in the lathe, multiplied upon the work; and when it is considered how many times in a year that defect is encountered, how many times it has performed its duties imperfectly, and how much extra labor in fitting and adjusting has become necessary, it will be readily perceived that it is better to throw away a dozen imperfect chucks, if needful, to obtain a good one.

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Chuck dogs are detached dogs which fit into the square holes of the chuck plate or face plate, being held to the plate by a nut and washer. These dogs are movable to any part of the plate, their position being regulated to conform to the shape of the work, which renders possible their employment in cases where a dog chuck would be of no service; such, for instance, as holding a triangular or irregular shaped piece of work. The centre line of the screw should stand exactly parallel to the face of the face plate, or tightening the screws, which in this case grip the work, will force the latter towards or away from the face of the plate, according to the direction in which the screws are out of true. The screws should have their ends turned down below the thread, and should be hardened as directed for bell chuck screws, since these screws may be also reversed in the dog for some kinds of work. The dog should be screwed very firmly against the face plate, so as to avoid their springing.

Universal or scroll chucks, containing screws or gear wheels which are enclosed, should be occasionally very freely supplied with oil, and the chuck worked so as to move the jaws back and forth to the extreme end of their movement, so as to wash out any particles of metal or dust which may have lodged or collected in them; for proper cleaning will reduce the natural wear to a minimum, and prevent the internal parts from cutting, as they are otherwise apt to do.

When the work is liable to spring, from the pressure of the jaws of a chuck, those jaws may be slacked back a little previous to taking the finishing cut, during which the work need not be held so tightly.

From what has been already said it will be obvious that it is of great importance that, in addition to the jaws of a chuck being well fitted to the plate, there should be a large amount of wearing surface, so as to prevent as far as possible the jaws wearing loose in their slides. This

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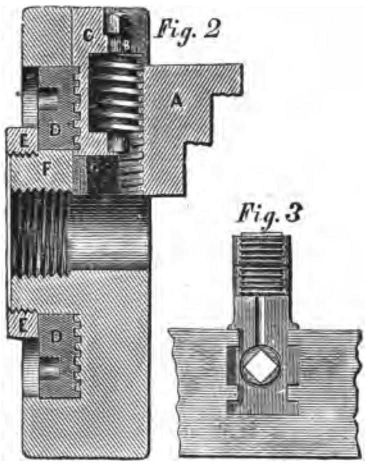
advantage is one of the main features in the Westcott chuck represented in Fig. 54 *a*.

Fig. 2 is a vertical section showing the manner in which the ring D engages in box C; also showing the position of screw B.

Fig. 3 is a section of the chuck, showing end of screw and box C; also manner in which all the parts are secured to the body of chuck. All screws and the boxes carrying the jaws are made of the best cast-steel, the jaws, wrenches, and scroll ring of the best hammered iron made especially

Fig. 54 *a.*



for the purpose. The jaws and all wearing parts are case-hardened.

The jaws are reversible, by which arrangement the small sized chucks can be used with facility in holding screws, pipes, drills, etc.; and the jaws can be operated independently of each other, when necessary, as well as operate concentrically and simultaneously. Hence square, round, oval, oblong, or eccentric shapes may be chucked with facility.

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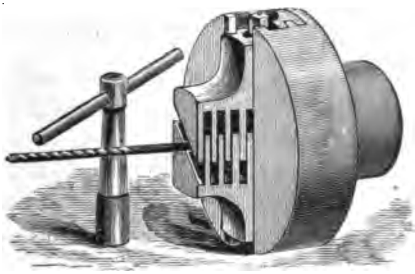
Another small chuck possessing a great advantage in having a large amount of wearing surface to prevent it wearing out of true is the Self-Centering Little Giant Drill chuck, which does the designer (Mr. Westcott) credit. A glance at the engraving (Fig. 54 *b*) will show that both

Fig. 54 *b.*



where the jaws slide in the chuck, and also outside of it, there is an unusual area of wearing surface presented, while at the same time the bearing of the jaws runs back deeply in the chuck, which is a great support to the jaws and an element to keep them from wearing out of true.

These chucks are supplied by H. S. Manning & Co., of 111 Liberty street, New York.

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CHAPTER VIII.

DRILLING IN THE LATHE.

We have next to consider drilling tools as they are employed in the lathe. For boring very small holes, as in centre-drilling, it is usual and advisable to revolve the drill and use the dead centre and its gear as a feed motion. For small lathes, a small chuck or face plate is made, it having a conical stem so as to fit into the hole into which the dead centre fits.

It is obvious that, as a lathe possesses no facilities for chucking work upon the tail stock, work which requires chucking, or is too heavy to be held conveniently in the hand, can only be drilled in the lathe by being chucked and revolved, the drill remaining stationary, and fitted into the socket in the tail stock spindle, or else suspended by being held by the work at the cutting end, and by the dead centre at the other end, and prevented from revolving by the aid of a drilling rest or a wrench. If the work revolves, it must of course be set to run true; and since the setting involves more work than would be required to hold it upon a drilling machine table, it follows that the lathe is only resorted to for drilling purposes in cases in which it is imperative to use it. These instances may be classified as follows:

1. Those in which very straight and true holes are required, and in which the point of ingress and egress may be centre-punched, in which cases (the back centre of the lathe being placed in the centre punch mark, and the point of the drill in the other) the drilling is sure to be true.

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2. Those in which the work being very long, can be got into the lathe in consequence of the movable tail stock, when it could not be got into the drilling machine.

3. Those in which, there being turning to be done besides the boring or drilling, the whole may be performed in the lathe.

4. Those in which the holes require to be very true, the work being chucked in the lathe.

The class first mentioned refers to small and light work only, and requires no comment, save that the work should be slowly revolved on the lathe centre while the drilling is progressing, so that the work will not drill out of true in consequence of its weight. The second will be treated of under the heading of the cone plate, or cone chuck, as it is sometimes termed; and the third (which usually comprises the fourth) we will proceed to discuss.

The spindle in the tail stocks of lathes are usually prevented from revolving by having a narrow groove along them, into which a small lug, stationary with, and projecting through, the bearing of the spindle, fits. If, therefore, a heavy strain, tending to twist the socket (as would be the case if a drill of a comparatively large size were held by it), is placed upon it, the groove, from its comparatively small wearing surface, soon gets worn as well as the lug, and the edge of the groove bulges, causing the socket to bind in its guide. Tail stock spindles are not, in fact, usually designed to perform such heavy duty; hence it is an error to assign it to them, unless, as is the case in some special lathes, the tail stock spindles, and hence their bearings, are made square to suit the spindles to carry drills for heavy duty. But drills above a half inch in diameter should be held by a centre in the shank end of the drill, into which the back or dead centre of the lathe may fit; the drill, if a round one, being held by a lathe dog fastened to it and resting against a piece of metal fastened in the tool post of the lathe, thus relieving

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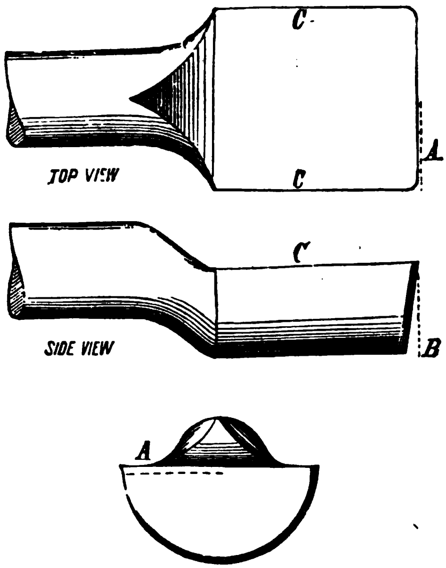
the tail stock spindle of the torsional pressure. If the shank of the drill is square, a wrench may be substituted for the dog or carrier.

HALF ROUND BITS.

For drilling or boring holes very true and parallel in the lathe, the half round bit shown in Fig. 55 is unsurpassed.

Fig. 55.



The cutting edge A is made by backing off the end, as denoted by the space between the lower end of the tool and the dotted line B, and performing its duty along the radius, as denoted by the dotted line in the end and top views.

It is only necessary to start the half round bit true, to insure its boring a hole of any depth, true, parallel, and very smooth. To start it, the face of the work should, if

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circumstances permit, be made true; this is not, however, positively necessary. A recess, true and of the same diameter as the bit, should be turned in the work, the bit then being placed in position, and the dead centre employed to feed it to its duty; which (if the end of the bit is square, if a flat place be filed upon it, or any other method of holding it sufficiently tight be employed) may be made as heavy as the belt will drive. So simple, positive and effective is the operation of this bit that (beyond starting it true and using it at a moderate cutting speed, with oil for wrought-iron and steel) no further instructions need be given for its use. It is made as follows:

Forge it as near to the required size as possible, leaving stuff sufficient to true it up, and from square steel if it is obtainable. Disregard the question of the cost of material, which, in a tool of this kind, does not represent six per cent. of the cost of the finished tool; whereas the difference in quality is as three to one. In order to turn the cutting end between the lathe centres, so as to have the centre at the shank end quite true with the turned part, it must be forged at the end to more than half the diameter, so as to leave sufficient metal to receive the centre hole and countersink whereon to turn it. The shank end should be forged square, and should, when centre-drilled, have a deep countersink. The cutting end must be turned true and smooth, being quite parallel, if to be used for parallel holes, and of the desired taper for taper holes. For parallel holes, all the cutting is performed by the end face A; but in taper holes, the side edges C, of the top face, also perform cutting duty, and hence the necessity of having the turned end of an exact thickness of half a diameter. After turning, and before removing it from the lathe, a tool having a point should be fastened in the slide rest, its point being made to bear lightly against the turned face, close to one of the edges C; and the rest should then be passed along so that the point will scribe a line true with

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the centre upon which the tool has been turned, which line will form a guide for filing the top face down to make the tool of the required thickness of one-half of its diameter. The edge A should be perfectly square with the side or diametrical edges C C. The circumference of the turned part should have the turning marks effaced with a very smooth file, by draw-filing the work lengthwise, care being taken to remove an even quantity all over. The rake of the tool, as denoted at the dotted line B, should not be greater in proportion than is there shown.

This tool should be tempered to a straw color and employed at a cutting speed of about fifteen feet per minute, and fed at a coarse feed by hand. For use on parallel holes, no part should be ground save the end face; whereas, in the case of taper ones, the top face may be ground, taking as little off as will answer the purpose. It should be borne in mind that, as the steel expands (and therefore becomes larger in diameter) by the process of hardening, the necessary allowance, which is about the one-hundredth of an inch per inch of diameter, should be made when turning it in the lathe. Tools of this description, which have a turned part to guide them, or those which depend upon the trueness of their outline or cutting edges to make them perform their duty, and which are apt, in the process of hardening, to get out of true (for all steel alters more or less during the operation of hardening), may be made true after the hardening or tempering by a process to be described in our future remarks on reamers, since it applies more directly to those tools than to half round bits.

To enlarge holes and true them out, the flat drill shown in Fig. 56 is employed. It is an ordinary drill made out of flat steel, having pieces of hard wood fastened to the cutting end, A being the steel, and B B the pieces of wood, held on by screws. When the drill has entered the hole far enough to make it of the diameter of the drill, the

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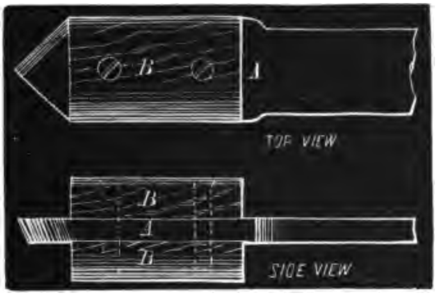
pieces of wood enter and fit the hole, steadying the drill and tending to keep it true. It is necessary, however, to true out the hole at the outer end before inserting the drill; for if the drill enters out of true, it will get worse as the work proceeds. The drill is fed to its duty by the back lathe centre, placed in the centre upon which the drill has been turned up.

The pieces of wood should be affixed before the drill is turned up, and so trued up with the drill, which should then be lightly draw-filed on the sides; and the cutting end having the necessary rake filed upon it, should be

Fig. 56.



tempered to a straw color, the pieces of wood being, of course, temporarily removed. For use on conical holes, the sides must be made of the requisite cone and the cutting speed in that case reduced (in consequence of the broad cutting surface) to about 10 feet per minute. (This speed will also serve in boring conical holes with a half round bit.) Such a drill is an excellent tool for ordinary work, such as pulleys, etc., because it will perform its duty very rapidly and maintain its standard size; and it requires but little skill in handling. It is more applicable, however, to cast-iron than to any other metal. After the outer end of the hole has been turned true and of the required size, to receive the drill, and when the latter is

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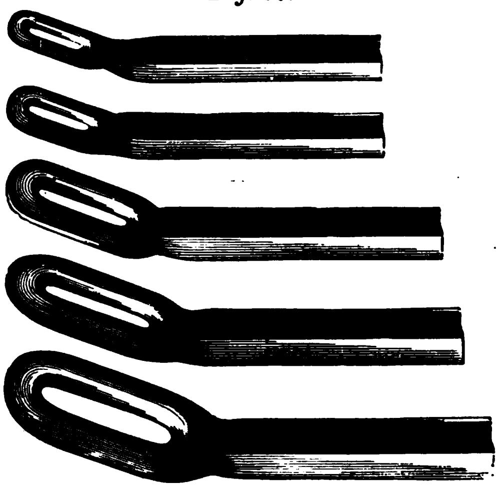
inserted for operation, it is an excellent plan to fasten a piece of metal, such as a lathe tool, into the tool post, and adjust the rest so that the end of the tool has light contact with the drill, so as to steady it. The lathe should be started, and the tool end wound in by the screw of the rest, until, the drill being true, the tool end just touches it, and having its end bevelled so as to have contact with the drill as close to the entrance of the hole as possible, in which position it is most effective. In all cases, when a drill is used in the lathe and remains stationary while the work revolves, this steadying implement should be employed, since it operates greatly to correct any tendency of the drill to spring out of true.

To hold flat drills, or those having square ends, and prevent them from revolving, a drill holder* may be

Fig. 57.



employed, either at the front end of the drill immediately behind the wood, or at the other end near the dead

* The above drill holders are sold by H. S. Manning.

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centre, the shape of the holder being as shown in Fig. 57, which shows four sizes. The angle of the eye to the body of the bar being so that the slide rest will stand off and not be close up to the chuck plate or the end of the work. It is well to keep the eye of the drill holder close to the entrance of the hole being drilled.

CUTTERS.

Cutters are steel bits, usually held in either a stock or bar being fitted and keyed to the same; by this means cutters of various shapes and sizes may be made to fit one stock or bar, thus obviating the necessity of having a multiplicity of these tools. Of cutter stocks, which are usually employed to cut holes of comparatively large diameter, as in the case of tube plates for boilers, there are two kinds, the simplest and easiest to be made being that shown in Fig. 58.

Fig. 58.

A is the stock, through which runs the slot or keyway into which the cutter B fits, being locked by the key C. D is a pin to steady the tool while it is in operation. Holes of the size of the pin D are first drilled in the work, into which the pin fits. To obviate the necessity of drilling these holes, some modern drill stocks have, in place of the pin D, a conical-ended pin which acts as a centre, and which fits into a centre punch mark made in the centre of the hole to be cut in the work. Most of these devices are patented, and the principle upon which they act will be

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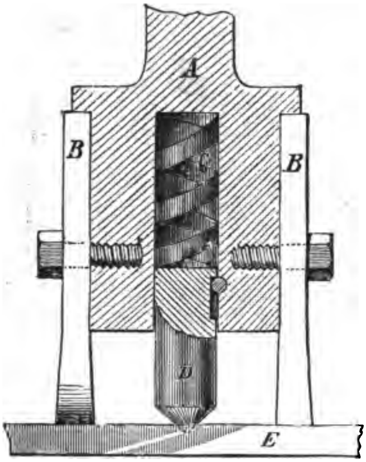
understood from Fig. 59, A being the stock to which the cutters B B are bolted with one or more screws. C is a spiral spring working in a hole in the stock to receive it. Into the outer end of this hole fits, at a working fit, the centre D, which is prevented from being forced out (from the pressure of the spring C) by the pin working in the recess, as shown. E is the plate to be cut out, from which it will be observed that the centre D is forced into the centre punch mark in the plate by the spring C, and thus serves as a guide to steady the cutters and cause them to revolve in a true circle, so that the necessity of first drilling a hole, as required in the employment of the form of stock shown in Fig. 58, is obviated. The cutters are broadest at the cutting edge, which is necessary to give the point clearance in the groove. They are also at the taper part (that is to say, the part projecting below the stock) made thinner behind than at the cutting edge, which is done to give the sides clearance. It is obvious that, with suitable cutters, various sized holes may be cut with one stock.

Fig. 59.

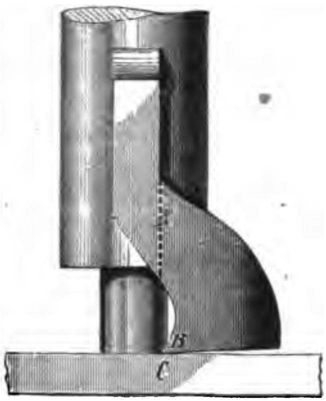


In cutting out holes of a large diameter in sheet-iron, a stock and cutter, such as shown in Fig. 60, is generally employed; but the great distance of the cutting edge from the stock centre, that is to say, the extreme length of the cutter bar, renders it very liable to spring, in which case these and other tools having a slight body and broad cutting

edge are almost sure to break, unless some provision is made so that the tool, in springing, will recede from and not advance into the cut. To accomplish this end, we must shape the cutter as shown in Fig. 60, which will, at the very least, double the efficiency of the tool.

In Fig. 60 the cutting edge B stands in the rear of the line A, or fulcrum from which the springing takes place; hence, when the tool springs, it will recede from the work C. To avoid springing and for very large holes, the cutter may be a short tool, held by a stout crossbar carried by the stock; but in any event the cutter should be made as shown above.

Fig. 60.



Cutters of a standard size, and intended to fit the pin stock, should be recessed to fit the end of the slot in the stock. In making these cutters they should be first fitted to the stock, and then turned up in the lathe, using the stock as a mandril, the ends being then backed off to form the cutting edges. Those slight in substance should be tempered to a light straw at the cutting edge, and left softer at the back part. Those above five-sixteenths of an inch in thickness may be hardened right out and not tempered at all.

Here it may be as well to describe a process for tempering cutters, which, as several very expert workmen have assured me, gives superior results. It is to heat the cutter to a cherry-red heat, and quench it in water until it is cold, and to then reheat it until water dropped upon it will dry off in slight bubbles. If, however, the reheat-

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ing is rapidly performed, there will be no need to drop any water on it, since that which adheres to it after quenching will be sufficient. I have no doubt but that for stout cutters, or even for slight ones which perform a light duty, this method is preferable to all others: but for light cutters performing a heavy duty, I should judge that it would leave them too hard for their strength, and therefore liable to break.

Cutters for boring bars should be, if intended to be of standard size, recessed to fit the bar, the bar having a flat place filed around and beyond the edges of the hole, to form a broader bearing for the cutter to fit upon. But, if the cutter is intended to vary the size of hole, it must be left plain, so that it may be moved inwards or outwards to accommodate the size of bore required. All cutters and bits should be used at a cutting speed of about 15 feet per minute, and with oil or soapy water for work in wrought-iron or steel; and for use on those metals, the cutters, etc., may be given a little front rake by grinding away the metal of the front face, as shown by the dotted line in Fig. 60, at B.

REAMERS.

Reamers are cutting tools usually employed to finish holes requiring to be very true and smooth, and may be employed in a machine or lathe, or by hand. As reamers are generally of a standard size, but little metal should be left to be cut out by the reamer, so that they will not, from excessive duty, become rapidly worn, and hence reduced in size. Fig. 61 represents reamers for hand use, No. 1 being a taper reamer to be introduced first, and No. 2 a finishing one to make the hole parallel. It is obvious that the taper one, by entering the hole a part of its length before its diameter becomes large enough to perform any cutting duty, is steadied during the operation. To steady the finishing reamer, it is usually made slightly taper at its cutting end for a length about equal to its diameter.

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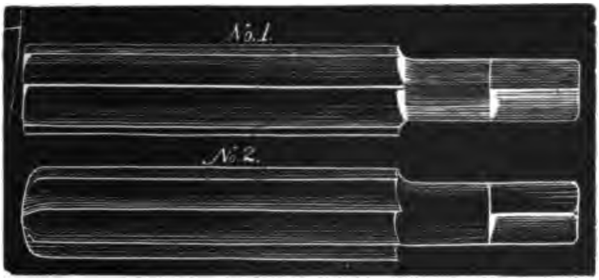
To illustrate the indispensability of this tool, we will take the case of fitting an eccentric rod double eye to a link or quadrant. The faces of the latter are planed, and the hole is bored as true and parallel as possible. The double eye may be planed, milled, or slotted, and the holes in the eyes bored as true as it is practicable to get them; nevertheless, when the double eye is fitted to the quadrant, it will be found that the holes in the eye and that through the quadrant are not true one with the other. Theory would say that they must come true, but practice proves that they never do; hence they are fitted together and the reamer is applied to true them out and make them parallel.

Fig. 61.



The reason for this want of truth is this: If the holes in the double eye are bored before the inside faces are cut out, the latter operation varies the form of the whole double eye, in consequence of freeing the tension which always exists on the outer service of either forgings or castings, as has already been explained in former remarks. If, on the other hand, the faces of the double eye are turned out first, then boring the hole will have the same effect; hence the use of the reamer cannot be dispensed with for holes requiring to be practically true.

Reamers should be made as follows: Forge them of the very best steel, and to within one-sixteenth inch of the finished size; then turn them up, taking care to properly

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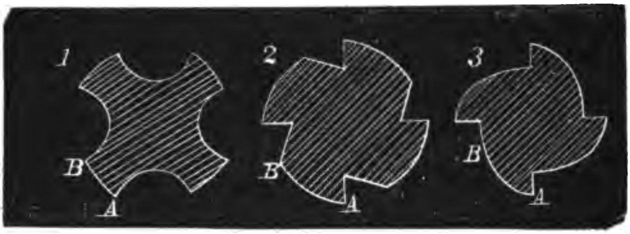
centre-drill and square the ends, and to rough them out all over before finishing any one part, bearing in mind that the diameter is sure to be a trifle increased by the process of hardening. Then cut out the flutes in a milling machine; the number of flutes should increase with the diameter of the reamer, but a good proportion is five flutes to a reamer of an inch diameter. Let the flutes be deep and roomy, so as to allow the cuttings free egress and the oil free ingress. An odd number of flutes is better than an even one, since they render the reamer less likely to follow any variation from roundness in the hole. Nor need the flutes be the same distance apart, a slight variation tending to steady the reamer when in operation. The form of flute is not arbitrary; Fig. 62 shows, however, the forms usually employed, either of

Fig. 62.



which will answer excellently for hand reamers, the only difference being that No. 2 is rather more difficult to sharpen (without softening it) on an emery wheel, while No. 1 is the most difficult to sharpen when it is softened, in consequence of the file being liable to slip out of the groove and take off the cutting edge.

After the flutes are cut, the rake is given to the cutting edges, by easing off or filing away the metal behind the cutting edges A, towards the point B; but this should be done by draw-filing to a very slight degree near the cutting edges, otherwise the reamer will be liable to wabble

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when cutting. In forms 1 and 2, the amount of the rake at the point B need not be more than the thickness of a piece of thin writing paper; but in No. 3, while near the cutting edge it may be very slight indeed, it must at the point B be considerable; hence (say for rough work requiring an excess of cutting duty) form No. 3 is not so desirable as the others.

The best method of hardening such reamers, and in fact all others, is to heat them in molten lead, and to quench them endwise in water; because when heated in lead the outside will become sufficiently heated before the inside metal is red hot; and so, when the tool is quenched, the inside or central metal will remain sufficiently soft to permit of the tool being straightened should it warp in the hardening. The straightening should be performed by slightly warming the reamer and laying it upon a block of lead, with the rounded side upwards; then place a rod of copper or brass in the uppermost flute, and strike the copper with the hammer. The use of the copper is to prevent damage to the tool by the hammer. The object of dipping the tool endwise is to prevent the reamer from warping in hardening. If great care is not taken in the hardening process, reamers, and all tools having grooves or flutes in them, are very apt to crack along the bottom of the flutes, which cracking is due to the unequal contraction of the metal in being rapidly cooled by quenching. Those having deep flutes, or sharp corners at the bottoms of the flutes, are the most liable to flaw in hardening, so that, in this respect, the flute shown in No. 1 is far preferable. To obviate the liability to flaw, the water in which the quenching is performed may be made sufficiently warm to be just bearable to the hand; and if it is also made a little saline, its hardening value will not have been impaired by the warming.

For light work, the hand reamer should be, if above three-quarter inch in diameter, tempered to a light straw color.

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For sizes less than that, and for heavy duty, a deep brown will prove the most serviceable, being less likely to cause the tool to break. The whole value of a reamer depends upon its being true or straight, and it is therefore necessary to exercise great care in the re-sharpening, as well as in its manufacture.

Many attempts have at various times been made to produce adjustable hand reamers, that is to say those formed of cutters held in a stock and adjustable as to diameter, the object being to make one reamer serve for several sizes of holes, and to render the manufacture less expensive by having to simply remove the cutters to grind them when dull, and to renew them when worn out. The difficulties in the way of producing such a tool are, that, in the smaller sizes, there is not sufficient strength to permit of their being made in pieces, and that, in requiring to set the diameter of the tool, a slight deviation as to size is very apt to occur. They are also liable to wear out of true.

The best and truest method of making long fluted reamers is the one instituted in the Grant Locomotive Works, of Paterson, N. J. It consists in turning the reamer from one sixty-fourth to one thirty-second inch too large in diameter; then, after cutting out the flutes and hardening, the straightening and backing off is performed as follows: upon the top of the slide rest, in the position usually occupied by the tool post or clamp, there is fastened a small head carrying an emery wheel of say eight inches diameter, upon a spindle having a small pulley attached, speeded to run about 2000 revolutions per minute. An overhead countershaft is provided to drive the same, the appearance of the device being as in Fig. 63. The belt is arranged to drive the emery wheel in a direction opposite to that in which the lathe runs.

A is the emery wheel, B the head carrying the spindle, and C the pulley, D being a lug to bolt the

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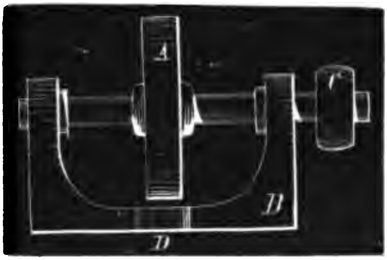
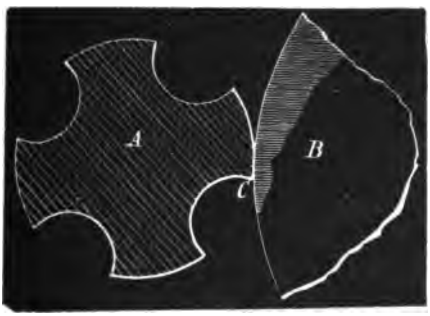
appliance to the top of the slide rest of the lathe. The reamer is, after being hardened, driven in the lathe at a fast speed; the revolving emery wheel is then brought into contact with it and traversed along the length, thus serving as a cutting tool to true the reamer to a dead true, and, by proper adjustment, to the requisite diameter. The backing off is performed thus: The lathe is stopped in

Fig. 63.



such a position that the emery wheel will make contact with the reamer just behind the cutting edge, as shown in Fig. 64; A being a section of the reamer, and B a section of the emery wheel, C being a cutting edge of the reamer. The position being adjusted, the lathe is locked, so that it cannot move, by locking the back gear or in any other convenient manner. The revolving emery wheel is then brought in contact with the reamer, and traversed from

Fig. 64.



end to end of its length of flute, thus performing the backing off, the reamer being turned a little further round

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and the grinding operation repeated until the backing off is completed upon that flute; the other flutes are then similarly treated, the whole process producing a true and sharp reamer, unequalled by any other method of manufacture. It is obvious that, by adjustment of the back head of the lathe, any desired degree of taper may be given to the reamer. The journals of the hardened spindles for lathes may be, and in fact are, in many cases, made true and round by the application of the same device.

For reaming out taper holes, such as are employed to receive taper pins, we have the square reamer. It is a piece of plain taper square steel, having all four faces ground level and straight, the four corners forming cutting edges. This tool should be dipped endwise in hardening, and tempered to a dark brown, leaving the square end on which the wrench (by which the reamer is revolved) fits of a blue color; because it is at times necessary to force it into its cut by striking it lightly with a hammer (a proceeding necessary with all reamers having appreciable taper upon them), which would break the edges of the square end off if they are left too hard. The end edges of the square head are bevelled off to prevent the head of the square end bulging from being hammered. To sharpen it, the flat sides are ground, taking care to keep them straight and the thickness even on the two diameters, so that, the sides being straight and the reamer square, it will cut taper holes whose sides will be straight. If the reamer is not ground square, two only of the edges will be liable to cut, causing the reamer to wabble, and so impairing its cutting power and rendering it liable to break. This description of reamer is sometimes used to cut out holes in boiler plates which do not come fair after being punched.

A half round reamer, similar to the half round bit used in the lathe, but made taper and with a square on one end to fit a wrench, will, however, work much more steadily in holes which do not come fair, and will bore at all times

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more true, though it will not cut so rapidly as a square reamer, when employed to bore a straight hole into a taper one. The method of making this tool is to turn it up and cut away half the diameter, tempering as directed for the square reamer.

Fig. 65.

Reamers for use by hand are sometimes made of the form shown in Fig. 65. The serrations forming the cutting edges are made to run up to about the middle of the length of the reamer. This description of reamer is employed to take out a very light cut only, and must be used as true as possible. Fewer cutting edges and flutes may be employed for heavier duty or for brass work, being much better qualified to carry off the cuttings. All reamers should be well supplied with oil for heavy cuts on steel or wrought-iron, and soapy water for fine finishing cuts on those metals; oil may also be used for brass work, providing the cut is very light and the cuttings can find very free egress.

SHELL REAMERS.

Shell reamers, such as shown in Fig. 66, are excellent tools for sizing purposes, that is, for taking a very light cut intended merely to smooth out the hole, and insure correctness in its bore or size. They are short reamers, having a conical hole running through the centre which is fitted to a cone mandril as a stock; thus three or four different sizes of reamers may fit to one stock. Through such stocks there should always be bored a hole into which a pin may be driven, projecting at each side of the stock to nearly the diameter of the shell reamer, in which there should, on each side, be filed a square groove to

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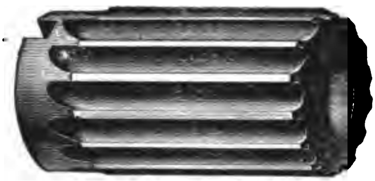
receive the pin. Thus the reamer will be prevented from slipping upon the mandril, as it is otherwise very apt to do.

Many attempts have been made to produce adjustable machine reamers having movable cutters, so that the size of the reamer may be varied by a change of cutters, and economy in sharpening and renewing is attained. None of these efforts, however, have met with such success as to cause their universal application. Of course such a tool is only applicable to sizes above an inch in diameter, because the division of a reamer of less than that size into two or more pieces weakens it so that it would not bear the necessary strain.

Fig. 66.



The best form of adjustable reamer of which I have any knowledge is that of one I designed and made for use on cast-iron work, though I have no doubt it would apply equally well to work in brass, wrought-iron, and steel. It proved a very serviceable tool, and is easily made, as a reference to Fig. 67 will show. A represents the stock, and D the cutters, C being a regulating washer, and D and E the tightening nut and washer. Each of the cutters B fits into a dovetail and taper groove in the stock, the shallow end of the groove being at the cutting end; so that if the regulating washer C is reduced in width, the cutters will slide forward and enlarge in diameter. The washer C is thus a means of adjusting the diameter of the cutters; and when the same is once adjusted, the nut D will lock it always to that precise diameter. If, therefore, several sets of cutters of different heights are fitted to one stock, and turned up while in the stock to the requisite diameter with the washer C in its place, we have a set of standard cutters which may always be placed in position

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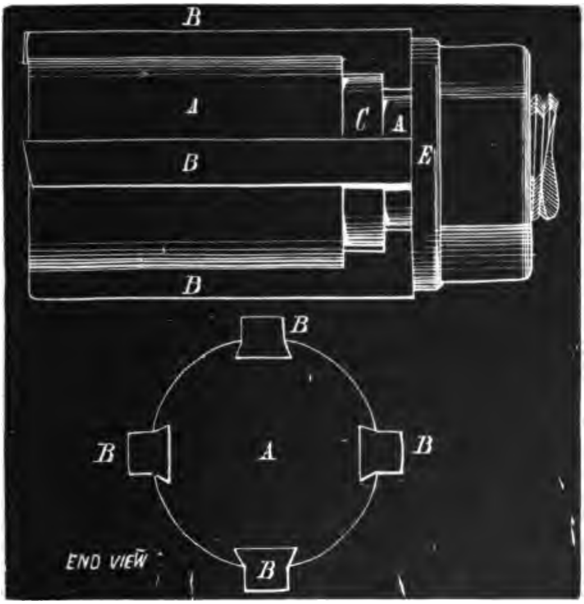
and locked up by the nut D, without measurement, since their sizes cannot vary. By providing another washer, very slightly thicker than the standard, the reamer will, in the case of each set of cutters, bore a hole to a driving fit, while a washer a trifle thinner will cause the cutters to bore a hole of an easily working fit. Thus the sizes of the cutters are regulated by the washer C, and not by measurement by the workman; they are therefore at all

Fig. 67.



times positive and equal. The cutters are backed off on the ends only, their tops being merely lightly draw-filed after being turned up, or they may be left one thirty-second of an inch too large, and ground off after hardening, by the grinding process already described. The cutters should be forged of the best cast-steel and tempered to a straw color.

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CHAPTER IX.

BORING BARS.

THE boring bar is one of the most important tools to be found in a machine shop, because the work it has to perform requires to be very accurately done; and since it is a somewhat expensive tool to make, and occupies a large amount of shop room, it is necessary to make one size of boring bar answer for as many sizes of hole as possible, which end can only be attained by making it thoroughly stiff and rigid. To this end a large amount of bearing and close fitting, using cast-iron as the material, are necessary, because cast-iron does not spring or deflect so easily as wrought-iron; but the centres into which the lathe centres fit are, if of cast-iron, very liable to cut and shift their position, thus throwing the bar out of true. It is, therefore, always preferable to bore and tap the ends of such bars, and to screw in a wrought-iron plug, taking care to screw it in very tightly, so that it shall not at any time become loose. The centres should be well drilled and of a comparatively large size, so as to have surface enough to suffer little from wear, and to well sustain the weight of the bar. The end surface surrounding the centres should be turned off quite true to keep the latter from wearing away from the high side, as they would do were one side higher than the other.

The smaller sizes of boring bars are usually simple parallel mandrils, having slots running through them, into which slots or keyways the cutters are fitted, being fastened by means of wedges. The backs of the cutters are tapered to the same degree as is the wedge, so that the key

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will bear evenly along both the edge of the keyway and the cutter. It is obvious that, if the cutter is turned up in the bar, and is of the exact size of the hole to be bored, it will require to stand true in the bar, and will therefore be able to cut on both ends, in which case the work may be fed up to it twice as fast as though only one edge were performing duty. To facilitate setting the cutter quite true, a flat and slightly taper surface should be filed on the bar at each end of the keyway, and the cutter should have a recess filed in it to fit the diameter of the bar so filed, so that after passing the cutter through the slot, it may be pushed forward in the manner of a jib, and then locked by the wedge. Such cutters not being adjustable, their diametrical edges need not have any clearance or rake on them, but the cutting corners should be rounded off, and the rake put on the end face of the cutter and carried around the round corner, the advantage being that the diametrical edge of the cutter will bear lightly against the bore of the work, and prevent the bar from springing.

Boring bar cutters, required to be adjustable, must not be provided with a recess, but must be left plain, so that they may be made to extend out on one side of the bar to cut any requisite size of bore; it is far preferable, however, to employ the recess and have a sufficient number of cutters to suit any size of hole, since, as already stated (there being in that case two cutting edges performing duty), the work may be fed up twice as fast as in the former case, in which only one cutting edge operates. This description of bar for use on small holes or bores is simply a mandril, and may be provided with several slots or keyways in its length, to facilitate facing off the ends of work which requires it. Since the work is fed to the cutter, it is obvious that the bar must be at least twice the length of the work, because the work is all on one side of the cutter at the commencement, and all on the other side at the conclusion of the boring operation. The excessive

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length of bar, thus rendered necessary, is the principal objection to this form of boring bar, because of its liability to spring. There should always be a keyway, slot, or cutter way in the exact centre of the length of the bar, so as to enable it to bore a hole as long as possible in proportion to the length of the boring bar, and a keyway or cutter-way at each end of the bar, for use in facing off. If, however, a boring bar is to be used for a job which does not require to be faced off at the ends, the keyway should be placed in such a position in the length of the bar as will best accommodate the work, and should then be made tapering in diameter from the keyway to the ends, a short piece at one end of the bar being made parallel to receive the driving clamp. A lug, however, by which to drive the bar, is sometimes cast on one end. This form of bar is stronger in proportion to its weight, and therefore less liable to spring from the cut or to deflect than is a parallel bar. The deflection of a bar, the length of which is excessive in proportion to its diameter, is sufficient to cause it to bore a hole of larger diameter in the centre of its length than at the ends, providing that the cutter is not recessed and does not cut on both sides—that is to say, when the cutter has the diametrical bearing against the diameter of the hole, they serve to steady the bar and prevent it from either springing away from the cut, or from deflecting in consequence of its own weight. The question of spring affects all boring bars; but in those which are used vertically, the deflection is of course obviated.

Here it may be mentioned that no machine using a boring bar should be allowed to stop while the finishing cut is being taken, for the following reasons: The friction, due to the severance of the metal being cut, causes it to heat to a slight degree, and to therefore expand to an appreciable extent; so that when the cutter makes its first revolution, it is operating upon metal at its normal temperature, but the heat created has expanded the bore of

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the work, and hence the cut taken by the second revolution of the cutter will be slightly less in diameter. This heating and expanding process continues as the cutting proceeds, so that if (after the cutter has made any number of revolutions) the bar is stopped and the cylinder or other work being bored becomes cool, when the cutter makes the next revolution it will be operating upon the bore unexpanded by the heat, and hence will cut deeper into the metal, until the metal, being reheated by the cut during the revolution, the boring proceeds upon expanded metal as before the stoppage; thus arresting the continuous progress of the cutter will have caused the cutting of a groove in the bore. Boring bars, for use in bores of a large diameter, are made with a head of increased diameter, the body of the bar being turned along its length and provided with a slot or key groove from end to end, the sliding head is bored to fit the bar, and is provided with a keyway. Thus the head may be keyed to the bar at any part of the length of the latter. Several cutters may be provided to the head, so that the work may be fed up rapidly; in such case, however, great exactitude is required in setting them, because there is no practical method of making them with a recess to insure their even projection from the bar, since the cutters are narrow, and generally cut across the whole diametrical face, so that each grinding affects their distance from the bar, and hence the size they bore.

A rude form of head may be made by simply cutting a slot or slots across it, and fastening the tool or tools therein, by means of wedges, and packing pieces, if necessary. The only advantage possessed by this kind of bar is that it will bore a round hole, even though the bar may run out of true, by reason of either or both of the centres being misplaced, or even though the bar itself may have become bent in its length. In addition, however, to its disadvantage as to excessive length, it possesses the further

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one that, unless a line drawn from the two centres upon which it revolves is parallel both perpendicularly and horizontally to the lathe bed, the hole bored will be oval and not round; or if the bar is not parallel horizontally with the shears, the hole will be widest perpendicularly, and *vice versâ*. To remedy these defects, we have the boring bar with the feeding head, which is similar to that described, save that the work remains stationary while the cutters are fed to the work by operating the head along the bar, which is accomplished as follows: either along the keyway or groove, or else through and along the centre of the boring bar, there is provided a feeding screw, passing through a nut which is attached to the sliding head. As the bar revolves upon its axis, the screw is, by means of suitable gearing, caused to revolve upon its own axis, as well as around the axis of the bar, thus winding the head along the length of the bar, and thus feeding it to the cut. If the screw runs along the centre of the bar, it is usually operated by gear wheels, the movement of the feed being continuous at all parts of the revolution; but if the screw is contained in a groove cut in the circumference of the bar, a common star feed may be attached to the end of the bar, in which case the feed of the whole revolution is given to the sliding head during that portion only of the revolution in which the outer arm of the star is moved by the projecting bolt or arm which operates it. From these directions, it will be readily perceived that a bar of the latter form, but having the screw in its centre, is the most preferable. Care must be taken, however, to keep these bars running quite true; for should either centre run out of true, the hole bored will be larger in diameter at that end; while on the other hand, should the bar become bent so as to run out of true in the middle of its length, the hole bored will be large in the middle if the work was chucked in the middle of the length of the bar; and otherwise it will be larger at one end.

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A very important consideration with reference to boring bars is the position which the cutters should occupy towards the head or the body of the bar. We have already been over the same ground with reference to parting or grooving tools for lathe work, cutting tools for planing work, and cutters for cutting out holes of a large diameter in boiler plates; but there are so many principles involved in the shape and holding position of cutting tools, so many variations, and so many instances in which the reasons for the adoption or variation of a principle are not obvious, that it is of vital importance to specify, in the case of each tool, its precise shape and position of application, together with the reasons therefor, the field of application being so extensive that the memory can hardly be relied upon. A careful survey of all the tools thus far treated upon will disclose that, in each case wherein the cutting edge stands in advance (in the direction in which the tool is moving, or, if the work move, in the direction of the metal to be cut) of the fulcrum upon which the tool is held, the springing of the tool causes it to dig into the work, deepening the cut, and in most cases causing the tool point or cutting edge to break; while in every instance this defect has been cured (upon tools liable to spring) by so bending or placing the tool that the fulcrum upon which it was held stood in advance of the cutting edge; and these rules are so universal that it may be said that pushing a tool renders it liable to spring into the work, and pulling it or dragging it enables it to take a greater cut and to spring away from excessive duty; and thus the latter prevents breakage and excessive spring, because, when the spring deepens the cut, it increases proportionally the causes of the spring, and creates a contention between the strength of the tool and the driving power of the machine, resulting in a victory for the one or the other, unless the work itself should give way, either by springing away from the tool and bending, or forcing it from the lathe centres or from the clamps which hold it.

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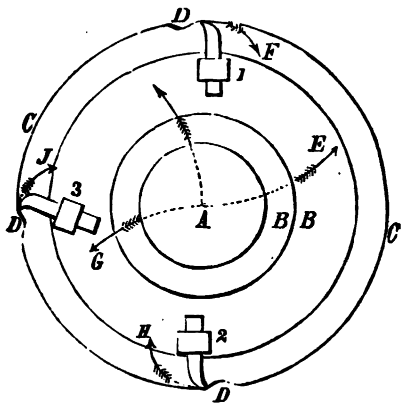
For instance, in Fig. 68 is shown A, a boring bar; B B is the sliding head; C C is the bore of the cylinder, and 1, 2, and 3 are tools in the positions shown. D D D are projections in the bore of the cylinder, causing an excessive amount of duty to be placed upon the cutters, as sometimes occurs when a cut of medium depth has been started. Such a cut increases on one side of the bore of the work until, becoming excessive, it causes the bar to tremble and

Fig. 68.



the cutters to chatter. In such a case, tool and position No. 1 would not be relieved of any duty, though it spring to a considerable degree; because the bar would spring in the direction denoted by the dotted line and arrow E, while the spring of the tool itself would be in the direction of the dotted line F. The tendency of the spring of the bar is to force the tool deeper into the cut instead of relieving it; while the tendency of the spring of the tool will scarcely affect the depth of the cut. Tool and position No. 2 would cause the bar to spring in the direction of the dotted line and arrow G, and the tool itself to spring in the direction of H, the spring of the bar being in a direc-

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tion to increase, and that of the tool to diminish, the cut. Tool and position No. 3 would, however, place the spring of the bar in a direction which would scarcely affect the depth of the cut, while the spring of the tool itself would be in a direction to give decided relief by springing away from its excessive duty. It must be borne in mind that even a stout bar of medium length will spring considerably from an ordinary roughing-out cut, though the latter be of an equal depth all round the bore and from end to end of the work. Position No. 3, in Fig. 68, then is decidedly preferable for the roughing-out cuts. In the finishing cuts, which should be very light ones, neither the bar nor the tool are so much affected by springing; but even here position No. 3 maintains its superiority, because, the tool being pulled, it operates somewhat as a scraper (though it may be as keen in shape as the other tools) and hence it cuts more smoothly. It possesses, it is true, the defect that the distance from the cutting point stands farther out from the holding clamp, and the tool is hence more apt to spring; and in cases where the diameter of the sliding head is much less than that of the hole to be bored, this defect may possess importance, and then position No. 2 may be preferable; but it is an error to employ a bar of small diameter compared to that of the work.

To obtain the very best and most rapid result, there should be but little space between the sliding head and the bore of the work; the bar itself should be as stout as is practicable, leaving the sliding head of sufficient strength; and if the bar revolves in journals, these should be of large diameter and with ample facilities for taking up both the diametrical and end play of the boxes, since the one steadies the bar while it is performing boring duty, and the other while it is facing off end faces, as for cylinder cover joints. The feed of a boring bar, which is slight in comparison to its duty, will range at from twenty to

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thirty revolutions to an inch of travel: while that of a stout bar, held in large and closely-fitting journals, may be about sixteen revolutions per inch of tool travel for roughing-out cuts, and four revolutions per inch of travel for finishing cuts, which may be made to leave the work very smooth indeed.

The tools employed for the roughing cuts should not have a broad cutting surface, and should have a little front rake. For the finishing cuts, the same tool may be employed, the end being ground to have, for use on cast-iron, a broad, level cutting surface along the cutting edge, so that, while the front edge of the tool is cutting, the behind part will scrape and thus smooth the cut. These tools should be made of the best quality of steel, and hardened right out, that is to say, not tempered at all.

The lip or top rake must, in case the bar should tremble during the finishing cut, be ground off, leaving the face level; and if, from the bar being too slight for its duty, it should still either chatter or jar, it will pay best to reduce the revolutions per minute of the bar, keeping the feed as coarse as possible, which will give the best results in a given time. In cases where, from the excessive length and smallness of the bar, it is difficult to prevent it from springing, the cutters must be made with no lip, and but a small amount of cutting surface; and the corner A should be bevelled off as shown. Under these conditions, the tool is the least likely to chatter or to spring into the cut, especially if held in position No. 3, in Fig. 68; for a tool which would jar violently in position No. 1 would cut smoothly and well if held in position No. 3.

The shape of the cutting corner of a cutter depends entirely upon the position of its clearance or rake. If the edge forming the diameter has no clearance upon it, the cutting being performed by the end edges, the cutter may be left with a square, slightly rounded, or bevelled corner; but if the cutter have clearance on its outside or diamet-

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rical edge, as shown on the cutters in Fig. 68, the cutting corner should be bevelled or rounded off, otherwise it will jar in taking a roughing cut, and chatter in taking a moderate cut. The principle is, that bevelling off the front edge of the cutter tends greatly to counteract a disposition to either jarring or chattering, especially as applied to brass work.

The only other precaution which can be taken to prevent, in exceptional cases, the spring of a boring bar is to provide a bearing at each end of the work, as, for instance, by bolting to the end of the work four iron plates, the ends being hollowed to fit the bar, and being so adjusted as to barely touch it; so that, while the bar will not be sprung by the plates, yet, if it tends to spring out of true, it will be prevented from doing so by contact with the hollow ends of the plates, which latter should have a wide bearing and be kept well lubricated.

It sometimes happens that from play in the journals of the machine, or from other causes, a boring bar will jar or chatter at the commencement of a bore, and will gradually cease to do so as the cut proceeds and the cutter gets a broader bearing on the work. Especially is this liable to occur in using cutters having no clearance on the diametrical edge; because, so soon as such a cutter has entered the bore for a short distance, the diametrical edge (fitting closely to the bore) acts as a guide to steady the cutter. If, however, the cutter has such clearance, the only perceptible reason is that the chattering ceases as soon as the cutting edge of the tool or cutter has lost its fibrous edges. The natural remedy for this would appear to be to apply the oil-stone; this, however, will either have no effect or make matters worse. It is, indeed, a far better plan to take the tool (after grinding) and rub the cutting edge into a piece of soft wood, and to apply oil to the tool during its first two or three cutting revolutions. The application of oil will often remedy a slight existing chattering of a boring bar,

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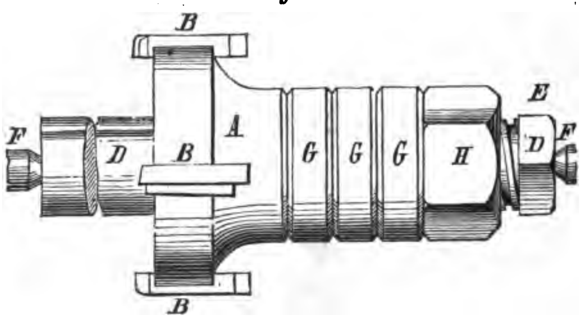
but it is an expedient to be avoided, if possible, since the diameter or bore cut with oil will vary from that cut dry, the latter being a trifle the larger.

The considerations, therefore, which determine the shape of a cutter to be employed are as follows: Cutters for use on a certain and unvarying size of bore should have no clearance on the diametrical edges, the cutting being performed by the end edge only. Cutters intended to be adjusted to suit bores of varying diameter should have clearance on the end and on the diametrical edges. For use on brass work, the cutting crown should be rounded off, and there should be no lip given to the cutting edge. For wrought-iron the cutter should be lipped, and oil or soapy water should be supplied to it during the operation. A slight lip should be given to cutters for use on cast-iron, unless, from slightness in the bar or other causes, there is a tendency to jarring, in which case no lip or front rake should be given.

SMALL BORING BARS.

In boring work chucked and revolved in the lathe, such, for instance, as axle boxes for locomotives, the boring shown in Fig. 69 is an excellent tool. A represents a

Fig. 69.



cutter head, which slides along, at a close working fit, upon the bar D D, and is provided with the cutters B B B, which are fastened into slots provided in the head A, by

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the keys shown. The bar D D has a thread cut upon part of its length, the remainder being plain, to fit the sliding head. One end is squared to receive a wrench, which, resting against the bed of the lathe, prevents the bar from revolving upon the lathe centre F F, by which the bar is held in the lathe. G G G are plain washers, provided to make up the distance between the thread and plain part of the bar, in cases where the sliding head A requires considerable lateral movement, there being more or fewer washers employed according to the distance along which the sliding head is required to move. The edges of these washers are chamfered off to prevent them from burring easily. To feed the cutters, the nut H is screwed up with a wrench.

The cutter head A is provided in its bore with two feathers, which slide in grooves provided in the bar D D, thus preventing the head from revolving upon the bar. It is obvious that this bar will, in consequence of its rigidity, take out a much heavier cut than would be possible with any boring tool, and furthermore that, there being four cutters, they can be fed up four times as fast as would be possible with a single tool or cutter. Care must, however, be exercised to so set the cutters that they will all project true radially, so that the depth of cut taken by each will be equal, or practically so; otherwise the feeding cannot progress any faster than if one cutter only were employed.

For use on bores of a standard size, the cutters may be made with a projecting feather, fitting into a groove provided in the head to receive them. The cutters should be fitted to their places, and each marked to its place; so that, if the keyways should vary a little in their radius from the centre of the bar, they will nevertheless be true when in use, if always placed in the slot in which they were turned up when made. By fitting in several sets of cutters and turning them up to standard sizes, correctness in the size of bore may be at all times insured, and the feeding may be performed very fast indeed.

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CHAPTER X.

LAPS.

A LAP is a mandril used to grind holes which are not quite true, are a trifle too small, or have been hardened and cannot therefore be cut by a tool. A lap may be simply a piece of rod copper, or an iron mandril with tin or lead cast around it. The diameter of a lap should be turned to be an easy fit at both ends in the hole and a trifle larger in the middle, so that the hole which it is intended to grind will fit tightly on the middle of the mandril, the latter being about three times the length of the former.

The operation is to place the lap through the hole which it is to grind, and then between the centres of the lathe; then, while the lathe is running at a high speed, supply the lap with oil and grain emery, moving the work back and forth along the lap until it will pass easily from end to end, when the lathe may be stopped and the lap indented with a cold chisel, and supplied with oil and emery, and the grinding operation proceeded with as before. The work should be held upright and on each side of the lathe alternately, so that its weight shall not cause the grinding to be excessive on one side of the hole.

Laps are sometimes used to grind out holes very true, smooth and parallel. In this case the work, after being bored as true and smooth as possible, is fastened to a table, such as a planer-table. The mandril for the lap should be very true, and, if a long one, tapered off in its diameter at the end, whereon the driver by which it is revolved is

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fitted, avoid its deflecting. The soft metal of the lap is turned quite true with the mandril, and a good working fit, the mandril having at the other end a long parallel point, which is a snug working fit, in a bearing which is also bolted to the said table, the hole in the bearing being set true with the hole in the work, which may be done by putting the lap in its place in the work and adjusting the bearing to the mandril. The end of the mandril which receives the driver, by which the lap is to be revolved by hand, may either run on a centre provided at the end of a screw, which centre must also be adjusted true with the hole to be lapped, and which must be screwed up to just bear against the mandril centre as the lap proceeds through the work; or else the driver end of the mandril may be made parallel and worked through a closely-fitting bearing, the same as at the other end. In either case the operation is to place very fine or flour emery and oil upon the lap, and while moving it back and forth to yet slowly revolve the lap in the hole, and when the lap becomes easy enough to pull and push it back and forth endwise of the hole, and to give it part of a revolution, and repeat the operation, continuing the operation until the job is made as true and smooth as is required. The last part of the process should be performed without the addition of any emery more than may be gathered from the outside of the hole in the work, which may be used over and over until it appears to have entirely lost all its cutting value. For very fine work it may be necessary to have several laps, since the lap soon wears down and is useless for fine work so soon as it becomes loose in the hole.

To grind small hardened flat surfaces true, a disc-lap similar to the face-plate (of a lathe), having no holes in it, may be employed; the face of the disc should be turned true and level and should be supplied with flour-emery and oil. In this case, however, the emery and oil are apt from centrifugal force to seek the outer diameter of the

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disc, hence they should be frequently carried by the finger back towards the centre. The outer diameter of such a lap runs much faster in feet per minute, and as a consequence grinds the work more. It is necessary, therefore, to press the work very evenly and lightly against the lap, and to revolve the work at the same time. No fresh emery should be applied to the lap during the later part of the operation, which may be finished with pure oil. All laps revolved in the lathe are run at a very fast speed.

ALLOWANCE FOR SHRINKAGE.

The amount of shrinkage to be allowed for contraction, on holes in cast-iron of two or less inches bore, should be so little that, the outside calipers being gauged to touch the shaft very lightly and the inside calipers or gauge to touch the hole only sufficiently to feel the touch, you can just see between the two when they are placed or gauged together.

For larger sized bores, proportionately increased, allowance should be made so that a hole of 12 inches diameter will have less than $\frac{1}{64}$ of an inch of shrinkage. Wrought-iron may be given a little more shrinkage, and steel one-half less in the case of the 12 inch hole.

If a band of iron or steel have too much allowance left on it for shrinkage, it will often burst from a sudden blow or jar; steel tyres have been known from this cause to break and fly off the wheel when the motion of the latter is great.

CRANK-PINS.

The cone part of a crank-pin should never have a flange or collar at the end near the journal, whether the flange is let into a recess or not. Such a flange causes the crank-pin to become loose in its seat, as has been demonstrated in English locomotives, in which, there being inside as well as outside frames to the driving or crank-axle, and the frames being very rigid, the strain on the crank-pin,

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especially on a curve, is very great, and hence crank-pins were apt to become loose. This defect has, however, been remedied by leaving the crank-pins a plain and slight taper from end to end of the seat, and having no flange in contact with the crank or wheel-hub (which receives the crank-pin).

CHUCKING BRASSES.

It is found in practice that, even under the most careful manipulation in clamping and boring boxes and bearings, their forms alter to an oval, of which the diameter across the joint is the smallest: so that they will not bed upon the crown as they should do. To remedy this difficulty the following methods are adopted: In small brasses—that is to say, those whose bore is four or less inches in diameter—the patterns for the two brasses are sometimes made in one piece, being joined together, by a narrow piece at the joint. The practice, then, is to fit the brasses to their places, and to bore them out to a diameter larger than that of the journal; then, after boring, to cut them in half at the joint, and let them sufficiently together; the result of the operation being that, even though the brasses close across the diameter, they will fit down upon the crown, and not bind across the joint. The objection to this plan is that the brasses will close across the diameter after they are bored and when they are cut in halves.

On connecting-rod and other brasses that are intended to key up tight together, the plan is sometimes adopted of boring them out a trifle too large for the journal, and then cutting away from the joint faces, where the two halves meet, sufficient metal to permit each half to bed upon the crown. This, however, is a tedious process, and the better plan is, before boring them, to place between those faces a piece of sheet-tin; or, if the bore of the work is greater than six inches diameter, two thicknesses of, say, double cross sheet-tin; and to cut off pieces of the same tin and place them beneath one end of the inside gauge, or one leg

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of the inside calipers, as the case may be; the same being set to the correct size of the journal, and care being taken to leave the bore a shade tight to the calipers or gauge, so as to leave a little to take out of the bore when fitting it, and thus obviate the necessity of having to file off the faces to let the two halves together while fitting them.

The brasses for fast-running journals should come brass and brass; that is, their faces should touch and lock together by the pressure due to the key or the bolts, as the case may be; so that when, in the fitting, the adjustment is so made as to permit of the key being driven tightly home, there is no danger of the pressure due to the key binding the brasses too tightly upon the journal, and thus causing it to heat. If the position of a box or brass renders it difficult to take it out from its place, and there is but little wear upon it, the joint of the brasses *may* be left open to permit of adjustment without filing off the faces; but if it is at all convenient to take out the top brass even, the brasses should be made to lock each other by the interposition between their faces of two liners or fitting strips, which strips may be taken out and filed thinner, when it becomes necessary to let the brasses together to take up the wear. To ascertain the thickness such liners require to be, a piece of lead wire may be placed between the brasses at each of the four corners, and the tightening up of the bolts or key will compress the wire to the requisite thickness. The liners, however, should be made a shade thicker than the wire compresses to, to relieve the journal from any undue pressure from the brasses. If the brasses have a comparatively large area upon the joint faces, and are made to come brass and brass, the faces may be cut partly away, thus reducing the area, and rendering the filing or letting together a more easy and expeditious operation.

In setting such brasses together, the joint faces should be

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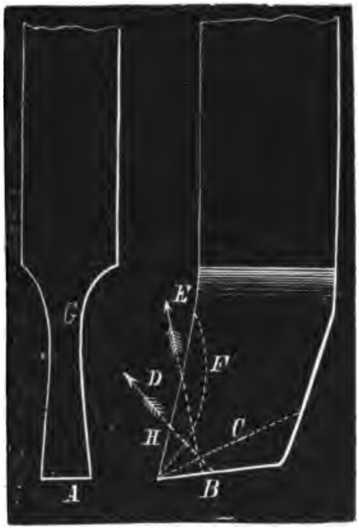
made true and square with the flange faces of the brass, so that locking the brasses together will not spring the latter out of true, and thus cause them to bind unduly upon the journal.

SLOTTING MACHINE TOOLS.

Tools for use in slotting machines are divided into two classes, those used by themselves, for holes in which there is not sufficient room to admit a tool-post or bar; and short tools, held in a tool-post on the bar, and fastened by a set screw or screws thereon provided.

Fig. 70.

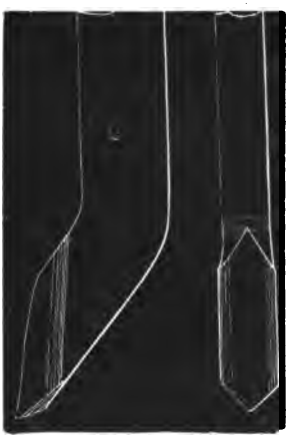


Referring to the first class, which should never be employed if it can be avoided, Fig. 70 is a tool for cutting out a key seat. The edge A is the cutting part, the thickness at G being reduced to make it clear the sides of the key seat. The face B receives the force necessary to bend the shaving, which, acting at a right angle to that face, tends (as will be observed) to force the tool deeper into the cut, at the angle shown by the dotted line and arrow E. Now suppose B to be ground to the angle shown by the dotted line C; the direction of the force required to bend the shaving would be in the direction of the dotted line and arrow D; and a comparison of D and F shows that an equal degree of spring would have more effect in deepening the cut of the tool in the case of D than in that of E; and it is this consideration which determines the

proper angle of the face B. It being obvious that the more angle it has the keener the cutting edge of the tool will be, and the greater the liability to force into the cut; and since the deeper the cut, the greater is the force required to bend the shavings, the tool continues to spring, digging into the work and either bending or breaking itself, or stopping the machine. Hence the face B should be made for slight tools, or for tools held far out from the tool-post, at about the angle shown above.

The face H should in all cases be made as shown above, and not hollowed at all in the direction shown by the dotted line F, which would not only weaken the tool, but would cause the cutting edge to be badly supported by the metal behind it, and hence to break; and these considerations, as to the shape and angle of the faces B and H, apply to all descriptions of slotting machine cutting tools, and are of more importance in the class of tools above shown than in tools used in any other kind of machine, because of the great distance they have, at times, to stand out from the holding screws or clamps.

Fig. 71.



A roughing out tool, held in the tool-post without the aid of a bar, should be made as shown in Fig. 71, concerning which nothing need be said save that it should be hardened right out, if the cutting edge stands close to the holding screws or clamps of the tool-post, and tempered to a light straw, if held far out from the same, which will, in the latter case, prevent it from breaking in consequence of any deepening of the cut from the tool springing.

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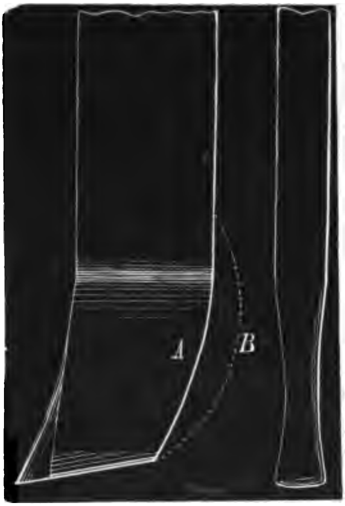
For cutting out a half round groove, the tool shown in Fig. 72 should be employed. The outline A is made as denoted by the dotted line B in cases where, from the narrowness of the tool, it is very liable to spring from the pressure of the cut, as, say, when the thickness at C is less than three-eighths inch, in which case the cutting edge should be lowered to a straw color; whereas, if thicker, the edge may be hardened right out. It is well here to note that it is advantageous that the tool should have a barely perceptible amount of spring, in the direction of D, in Fig. 71, because otherwise the edge of the tool will rub against the work during the back stroke, and thus become rapidly dulled.

Fig. 72.



Whenever the nature of the work to be done will admit, a holding bar and short tool, such as shown in Fig. 73, may be used.

By using such a bar, short tools, such as have been already described for use in the lathe or planer, may be employed, their shortness rendering their grinding and forging much easier of accomplishment. Many of these holding bars have small pivoted boxes, similar to that shown in Fig. 73, provided to receive the tool. A is a sectional view of the bar, B is the box, pivoted at C, D is the tool, and E the set screw for holding the same. It will be observed that the set screw E screws into the pivoted box, and not into the end of the bar, and that the

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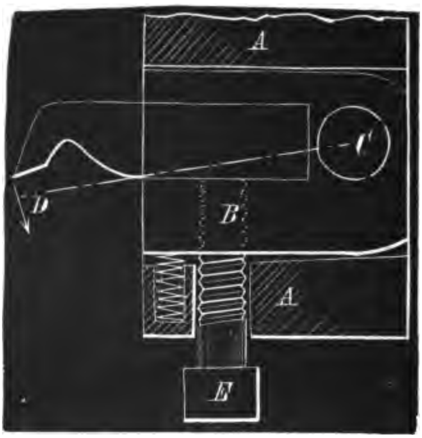
hole, provided in the end of the bar to admit the set screw, is large enough to permit the set screw to have plenty of play or movement. The object of this and similarly designed devices is to allow the tool to move, in the direction of D, off the pivot C, and thus to prevent the tool edge from rubbing against the sides of its cut during the up stroke of the bar, the spiral spring shown being made sufficiently strong to support the box B in the position shown, but not sufficiently strong to resist much force exerted upon the tool and in the direction of D. For small or even medium sized work these devices are

Fig. 73.



very efficient; but for large, heavy, outside work, the bars themselves are too slight, and it is usual to employ a similar device (on a large scale) provided in the tool end of the slide itself. Under these conditions the slotting machine will perform as heavy duty as either the lathe or planing machine. The writer has in his possession a cutting taken off the outside of a crank at the Morgan Iron Works, which cutting was taken at a cut $2\frac{5}{8}$ inches deep, and is a full $\frac{1}{8}$ of an inch in thickness, the tool employed being

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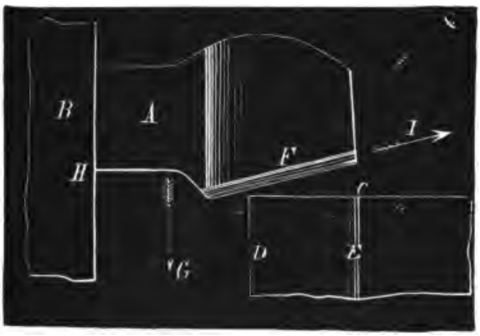
a knife tool, ground as shown in Fig. 74. B represents the tool end of the slide of the slotting machine, A the knife tool, C the work, and from D to E the depth of the cut.

The face of the tool is ground off at an angle, in the direction of I, so that the point of the tool shall not break off when it strikes the work, and so that the strain upon the tool and working parts of the machine shall not come upon them too suddenly, and cause them to break, as would be the case were the cutting edge of the tool to strike the cut along its whole length simultaneously. As

Fig. 74.



shown in the engraving, the tool would strike the work at F on the edge only, which would for an instant of time exert only enough resistance to bring all the working parts of the machine to a bearing; and as the tool descended, the strain would gradually increase until the point of the tool reached the work. When the tool is near the end of the stroke, and therefore leaves the cut, it will do so at F first, thus leaving the cut gradually, and greatly modifying the jump due to the recoil of the working parts of the machine when relieved of the heavy strain necessary to drive such a deep and thick cut. The enormous strain

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placed upon the tool would inevitably break it were it left very hard; it is therefore tempered to a purple.

No other tool can well be used for taking such heavy cuts, because grinding off the face, F, of any other tool would not leave the tool edge sufficiently keen to sever the metal without an excessive amount of driving power; and further, because the breadth of the face F, which sustains the force necessary to bend the cutting, is narrower in the knife tool than in any other, and therefore bends the cutting less, experiencing a corresponding decrease of strain. Cuts of such great depth and thickness cannot be well taken in slotting machines whose slides are operated by a connecting rod or link, because the excessive strain would be apt to force the connecting rod along the slot provided to alter the stroke of the machine; the sliding head is therefore provided with a strong rack on each side, operated by pinions, with suitable reversing gearing attached for varying the stroke.

When operating the feed of a slotting machine by hand, the work should be fed to the cut while the tool is reversing its motion at the top of the stroke, and not while the tool is cutting or at the bottom of the stroke, because, in either of the latter cases, the tool edge would grind against the sides of the cut during the up stroke, which would soon impair the cutting qualifications of the tool.

Tool-holding bars of sizes below about 1½ inches in thickness should be made of steel so as to be strong enough to resist the tendency to spring. For sizes above that they may be made of wrought-iron.

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CHAPTER XI.

Fig. 75.

TWIST DRILLS.

TWIST drills are not, as is usually supposed, of the same diameter from end to end of the twist, but are slightly taper, diminishing towards the shank end. The taper is usually, however, so slight as to be of little consequence in actual practice. Neither are twist drills round, the diameter being eased away from a short distance behind the advance or cutting edge of the flute, backward to the next flute, so as to reduce the friction of the sides of the drill upon the hole and give the sides of the drill as much clearance as possible. The advance edges of the flutes are left of a full circle, which maintains the diameter of the drill and steadies it in the hole. If, from excessive duty, that part left a full circle should wear away at the cutting end of the drill, leaving the corner of the drill rounded, the drill must be ground sufficiently to cut away entirely the worn part, otherwise it will totally impair the value of the drill, causing it to grind against the metal, and no amount of pressure will cause it to cut. The advantage over other drills possessed by the twist drill is that the cuttings can find free egress, which effects a great saving of time, for plain drills have to be frequently withdrawn from the hole to extract the cuttings, which would jamb between the sides of the hole and the sides of the drill, and the pressure will frequently become so great as to twist or break the shank of the drill, especially in small

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holes. In point of fact, the advent of twist drills has rendered the employment of any other form for use in small holes (that is to say, from ½ inch downwards) totally inexcusable, except it be for metal so hard as to require a drill tempered to suit the work. Other advantages of the twist drill are that it always runs true, requires no reforging or tempering, and, by reason of its shape, fits closely to the hole, and hence drills a very straight and smooth hole; and, having a line drawn down the centre of each flute, it is easy, using the line as a guide, to grind the drill true, and not one-sided. It is also not liable to be influenced so much by an air or other hole or soft spot which may exist in the metal being drilled. These qualifications render the twist drill a very superior tool for the finer classes of work, and for such purposes as drilling metal away to form a keyway or slot; for in the latter case, the holes may be drilled so closely together that they will run one into the other. A common flat drill is incapable of performing such work. Twist drills will drill brass admirably, providing the cutting edge is made long by grinding it well back on the diameter of the drill, that is to say, by making the two cutting edges stand at a more acute angle one to the other. The twist drill will not, however (in holes of a moderate depth, that is to say, holes whose depth is not more than four times their diameter), do so much duty in a given time as a common drill, especially in iron or steel, if the latter be slightly lipped: the reason being that the latter, stronger in proportion to its diameter, will stand more strain, and may therefore be fed much more rapidly in all cases wherein the depth is not too great to permit the cuttings from finding egress before becoming jammed in the hole.*

FEEDING DRILLS.

Much more duty may be obtained from a drill by feeding

* These drills are kept in stock by H. S. Manning, 111 Liberty street New York.

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it by hand than by permitting the gearing of the machine to feed it, because in hand feeding, the sense of feeling indicates to the operator how much cut the drill is capable of standing, and he can therefore vary the rate of feed, keeping it up to the maximum obtainable on the degree of hardness of the metal being drilled. Dullness of the cutting edges, hard or soft spots in the metal, or any other variation in the condition of the drill or in the metal being drilled, is at once perceived by hand feeding. Drilling machines have, it is true, several degrees of feed, but the fact is that the human hand can feed the drill at any rate that can be obtained by means of machine gearing; and having behind it the human mind, it is enabled to accommodate itself to the numerous and variable conditions against which no provision can be made in automatic feed gearing. No positive rate of feed, either for any size of drill, or for any particular kind of metal, can be given, because of the always present variations in the degree of hardness of the metal to be cut, and furthermore because, in the case of iron and steel, the facility of supplying the cutting edges with oil seriously affects the attainable rate of feed to the drill. If, for instance, the hole is being drilled horizontally, as in a lathe, and is very deep, so that it is difficult to freely supply the cutting end of the drill with oil, the feeding must proceed slowly or the cutting edges of the drill will soon become destroyed. Here, also, it may be well to state that, if oil be supplied to a drill cutting cast-iron or brass, it will cause the cuttings to jamb between the sides of the drill and the sides of the hole, until the pressure becomes so great as to either stop the drilling machine or lathe, or else twist or break the drill. The rate of feed, and the speed at which the drill should revolve, depend upon the hardness of the metal under operation, although not to a very great extent, except in the event of the metal being unusually hard, in which case the drill should revolve very slowly; for not

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much latitude in the degree of hardness of the drill is permissible, for fear of impairing the strength of the drill.

DRILLS AND DRILLING—FLAT DRILLS.

A drill is, all things considered, the most effective tool employed by the machinist; for while its cutting edges are necessarily of decidedly undesirable angles and form, it sustains the very roughest of usage, and yet will bear more strain in proportion to its strength than any other cutting tool. The reason of this is that it is supported by the metal upon which it is operating, and is thus prevented from springing away from its duty. This support may be of two kinds, first that due to the wedge shape of the main cutting edges, one to the other, and second, that to be derived from making the diameter of the drill parallel for some little distance behind the cutting edges, so that the sides of the drill, by contact with the sides of the hole, serve to guide and support the drill. The latter, however, only comes into operation at and after such time as the drill has entered the metal sufficiently deep to drill a recess of the full diameter of the drill.

The support given to the drill, in the first instance cited, arises from the tendency of either of the cutting edges to spring away from the cut, which is, of course, counterbalanced by the opposite cutting edge having the same tendency, but in an opposite direction, so that between the two the drill is held to a central position; and also from the tendency of the drill point to force itself forward (by reason of the pressure behind it) as far into the cone formed by the end of the hole as possible, as the end of the hole and the cutting end of the drill are two cones, one being forced into the other. In a drill properly ground (that is, having its cutting edges at an equal angle to the centre line of the length of the drill, and the cutting edges of an equal length from the centre or point of junction of the cutting edges) both the cutting edges and the

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sides of the drill act as supports and guides, tending to sustain it under the strain and keep it true. If, however, the drill is not ground true, the strain upon it becomes very great, because the whole force of the cut is then placed upon one cutting edge only, and is continuously tending to thrust the point of the drill outwards from the centre of the hole being drilled, hence cutting a hole larger in diameter than the cutting part of the drill—that is to say, a hole whose diameter will be twice that of the radius of the longest cutting edge of the drill, measured from the centre line of the length of the drill. If, under such conditions, one side of the drill bears against the sides of the hole, there will be created two opposing forces, independent of the strain necessary to sever the metal, one being the endeavor of the point of the drill to keep to the centre of the hole, because of the conical shape of the end of the hole and point of the drill, and the other being the endeavor of the cutting edge to force the drill to one side, and force the point of the drill out of the centre of the hole. And as the pressure of the side of the drill against the side of the hole will tend to force the drill to revolve true with that side of the drill so that the point of the drill will revolve in a circle and not upon its own axis, the result will be a hole, neither round, straight, nor of any definite diameter, as compared to the diameter of the drill.

Drills that are a trifle too small for the required size are sometimes purposely ground a little out of true so as to cause the hole to be larger than the drill, but the action of such drills is distorted, and it is impossible to estimate exactly how much deviation is necessary to the required increase of diameter of the hole. Part of the power driving the drill is lost, the loss being due to the creation of the above opposing forces, and the drilling operation is slow by reason of only one edge of the drill performing any cutting. Hence the feed of the drill being only half as rapid as it should be, it is an unmechanical expedient and

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a loss of time, especially if the hole is to be drilled clear through the metal: for in that case, as soon as the point of the drill emerges through the metal and the drill is therefore released from its influence, the cutting edges will gradually adjust themselves to the hole, and drill the remainder of the hole to the size of the diameter of the drill; when finished thus, the end of the hole where the drill emerges will be conical and of smaller diameter, and will therefore require to be filed out, entailing in all more loss of time than would be required to make a drill of the proper diameter.

The importance, then, of taking especial pains to grind a drill true being apparent, we may next consider how thick the point of the drill should be. It is here that the main defect of the drill as a cutting tool lies, for it is impossible to make the cutting edge across the centre of the drill (that is, the cutting edge across the thickness of the drill, connecting the cutting edge on one side of the drill to the cutting edge of the other side) sufficiently keen to enable it to enter the metal easily, without grinding the angles of the two cutting edges very acute, which would so weaken the cutting edges as to cause them to break from the pressure of even the lightest feeding. The only alternative, then, is to make the point of the drill as thin as is compatible with sufficient strength; and this will be found to be of about the following proportion:

Diameter of drill.	Thickness at point.
1-8 inch	1-64 inch
1-4 "	1-32 "
3-8 "	3-64 "
1-2 "	1-16 "
5-8 "	1-16 "
3-4 "	1-16 "
7-8 "	1-16 "
1 "	3-32 "

The flat face must be made gradually thicker as the full diameter of the drill is reached.

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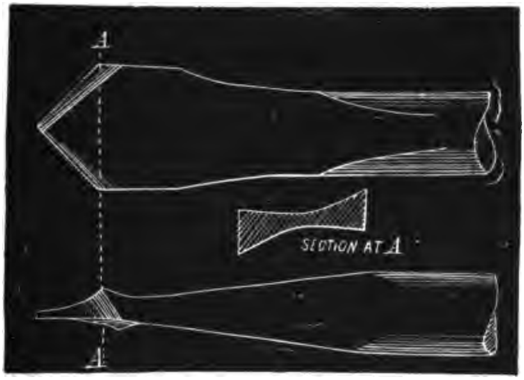
The angle at which to grind the end of the drill is governed to a large extent by the kind and degree of hardness of the metal to be drilled, the angle shown in Fig. 75 being suitable for wrought-iron, steel, or unusually hard cast-iron; while, for common cast-iron or brass, a little more angle may be given. But no definite angle can be given for any metal, because of the varying conditions under which a drill performs its duty. From these considerations we find that the effectiveness of a drill arises from the support rendered to it by the work, which more than compensates for the want of keenness inherent to its form of cutting edge. Not much rake should be given to any drill, otherwise the cutting edges will break.

Thus far, however, we have been considering the ordinary flat drill in its most simple form. For use on steel, wrought-iron, and cast-iron, we may improve the cutting qualifications of the drill by bending each side of the cutting bevel edges forward, thus forming what is termed a lip drill, as shown in Fig. 76. Such a drill will cut with

Fig. 76.



much greater ease and rapidity, because the angle of the two faces whose junction forms a cutting edge is much more acute, while the cutting edge is, at the same time,

well supported by the metal behind it, which advantages are to be obtained in no other way. The cutting edges of this drill are similar to those on the twist drill.

DRILLING HARD METALS.

Very hard metal, such as steel tempered to a blue, may be drilled by a drill tempered to a deep straw color, the drill being used at a comparatively slow speed, and forced against the work as hard as possible without breaking the point of the drill. Sufficient oil may be applied, after the point of the drill has entered the metal, to keep the cutting edges barely moist, the drill being again allowed to run dry and again moistened, thus using as small an amount of oil as is consistent with keeping the drill cool. In this way the drill will cut hard steel the best. For cast-iron, however, the drill should be kept as dry as possible. In drilling cast-iron that is very hard, and also wrought-iron that has been case-hardened, the operation may be greatly assisted by taking a hammer and a chisel, and jagging the surface of the metal, thus enabling the edges of the drill to bite it.

If necessary, the chisel may be made very hard for this especial purpose.

To make a drill exceedingly hard to suit some especial case, it may be heated in a charcoal fire to a dull red heat, and quenched in mercury instead of water. Another method is to heat the drill to a red heat in molten lead, and then to drive it into a block of cold lead, striking successive blows lightly and quickly until the drill is sufficiently cool to permit of its being held in the hand. The cases, however, in which a drill is required to be so hard are exceedingly rare.

If a drill squeaks while being operated, it arises from one of two causes: either the cutting edges are dull, and require grinding, or else the cuttings are binding in the holes. In the first case, immediate grinding is necessary; in the second, the drill should be withdrawn and the cut-

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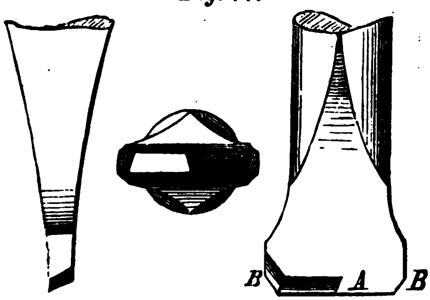
tings extracted. Twist drills will bring out most of the cuttings of themselves, but a piece of wire, spoon-shaped at the end, is necessary when plain drills are used.

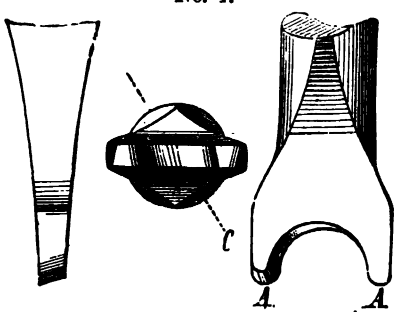
SLOTTING OR KEYWAY DRILLS.

For drilling out oblong holes, such as keyways, or for cutting out recesses such as are required to receive short feathers in shafts, the drill known as a slotting drill, shown in Fig. 77, is brought into requisition. No. 1 is the form

Fig. 77.



No. 1.



No. 2.

in which this tool was employed in the early days of its introduction; it is the stronger form of the two, and will take the heaviest cut. The objection to it, however, is

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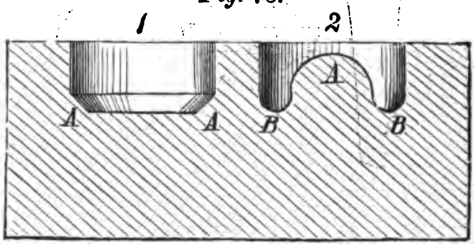
that, in cutting out deep slots, it is apt to drill out of true, the hole gradually running to one side. Suppose, for instance, as is sometimes the case, the slot or keyway is so deep that it becomes desirable to avoid having an extra long drill, which would be liable to bend and spring from the pressure of the cut, and hence that a shorter drill is used, drilling the keyway half way from each side; the tendency of such a drill would be to run to one side, so that the junction of the halves drilled from each side will not come fair.

The drill having entered on one side, and then on the other side, and having cut down until it arrived at the centre, and hence cut the keyway clear through the metal, and the junction of the two not being even at centre, it is evident that the keyway will require considerable filing to make the faces so true, level, and parallel that the key will fit all the way through. To remedy this defect, the form of drill shown in No. 2 has been brought into use. It will be observed that it enters the metal at the points A A first, and therefore cuts a ring of metal out, leaving a projecting piece in the centre which serves as a guide to steady it; whereas form No. 1 cuts a flat-bottomed hole. So that, if both drills were simply rotated and fed as a common drill, the holes made by them would appear as in Fig. 78. It

Fig. 78.



will be observed that in No. 1 the bevelled corners A alone steady the drill, while in No. 2 there is the whole

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core A tending to steady it, in addition to the round corners B B. In practice, however, only the round corners act to steady it, because of the light depth of the cut. These drills, are, however, never used to bore round holes, but oblong ones only, which is accomplished by either causing the drill to travel back and forth to the required length of the hole, the work being held stationary, or else by revolving the drill in a stationary position, while the table to which the work is bolted travels back and forth to the requisite distance, the cut in either case being fed to the drill at each end of the travel. Thus a slot equal to the length of the travel of the work or the drill, as the case may be, and of a width equal to the diameter of the drill, is made. If drill No. 1 is employed to cut a recess, it will leave an angular corner, while No. 2 will of course leave a round one, the bottom of the recess in either case being left quite flat, since the bottom of No. 1 is flat of itself, while the rounded corner of No. 2 cuts away as it travels along, the cone A, which, as shown in Fig. 78, is made when neither the drill nor the work travels.

Slot drill No. 1 is made by filing the cutting end square, level and true to the requisite diameter and shape, and then backing off, that is filing away on one side, the edges from the centre of the drill, outwards and across the bevelled corner, as shown in Fig. 77; while No. 2 is made by filing up the cutting end true, level, and square, and then filing out the curved hollow centrally in the end face, with a round file held at an angle with the centre line of the width of the drill, as shown by the dotted line C, in the end view of No. 2 in Fig. 77, after which the corners A A should be rounded and backed off. The thickness at the cutting end of drill No. 1 should be the same as that given for common drills, while No. 2 may be left somewhat thicker, to give it extra strength, since its form renders it comparatively weak. The reason for keeping the end of No. 1 as thin as a common drill is, that it has, at the junc-

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tion of its two cutting edges, centrally on the end face and between the bevelled corners, a cutting edge across the thickness of the drill, as shown in end view, Fig. 77, and is in that respect subject to the defect before mentioned as inherent in common drills. This defect does not, however, exist in slotting drill No. 2, in which the cutting edges on the outside faces extend clear to the centre of the diameter of the drill.

Slotting drills should be tempered to a deep brown, and should be supplied freely with oil when employed to cut wrought-iron or steel, but must be kept perfectly dry when used upon cast-iron or brass. They are revolved at a higher rate of speed than common drills. To employ them in a common drilling machine whose table has no horizontal sliding motion, it is necessary to make a chuck which will bolt to the machine table; the chuck is to be provided with a pair of jaws to clamp the work, and to make the upper part of the chuck movable upon a slide in the lower part.

In using such a chuck, the operator will be very apt to vary the distance to which he moves the slide at each cut, the effect of such variation being to cause the edge of the slot or keyway to be very uneven. To remedy this, it is best, after having drilled to the proper depth, to wind the slide and set the drill so that it takes a slight cut out of one end of the slot at the top, and then (keeping the chuck stationary) to feed the drill down through the slot, thus cutting the end out quite even. In taking the first few cuts at the commencement of the operation, that is to say, immediately after the work is chucked, it is better to cut the slot a little less than the required breadth, so as to leave a little to come out of each end of the slot (as above described) to true it. It is obvious that parallel strips may be employed in the jaws, whereon to rest the work, or to make up the width between the ends of the screws, and the opposite jaw of the chuck.

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There is probably no one cutting tool used in a machine which saves so much labor as the slotting drill, because it performs a duty that no other tool or machine can perform, and which is moreover a most difficult and tedious one. Before the advent of this tool, deep keyways were cut out of the solid metal in the following manner: first, plain holes were drilled through the work, then these holes were plugged up by having pieces of round iron driven tightly in them. Then new holes were drilled, the centre of each new hole being in the thin wall of solid metal between the plugged holes. After the latter holes were drilled, the remains of the plugs were driven out, the sides of the keyway would present a serrated appearance. This entailed an almost incredible amount of chipping and filing in order to make the sides of the keyway level and true, and the width parallel. This method of procedure is, however, still in vogue to a slight extent, being confined mainly to jobbing and repair shops. It is also employed for very narrow and deep holes, since a slotting drill cannot be employed to advantage in holes of less than about $\frac{5}{16}$ of an inch in diameter, because of the bending and springing of the drill. If, however, twist drills are employed to drill the small holes, the plugging with pieces of iron may be dispensed with, since the holes may be drilled so as to run one into the other; in this case every other hole should be drilled first, and then in drilling the intermediate holes the drill will not run to one side or the other.

It may here be observed that the principles of the action of the slot drill have been applied to a variety of purposes in woodworking, prominent among which is its use in Boult's panelling and dovetailing machine. In its adaptation to wood, as in its adaptation to iron, there is no other tool at all capable of performing the same kind of duty, irrespective of either time or quality.

Keyways or slots that are wide enough to admit a stout

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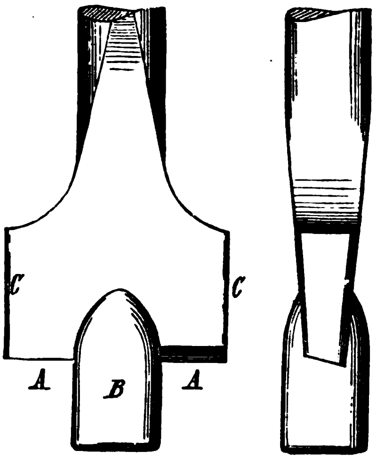
tool may be cut by drilling a hole the width of the required keyway at one end, and then cutting out the remainder of the keyway in the slotting machine. All ordinary keyways, however, are cut quicker and better with the slot drill.

PIN DRILLS.

The next form in which the drill appears is the pin drill, which is a drill having a pin projecting beyond and between its cutting edges, as shown in Fig. 79, A A being the cutting edges.

Fig. 79.



The purpose of this drill is to face off the metal round the outside of holes, the pin B fitting into the hole so as to steady the drill and keep it true with the hole. In making this tool, the pin B, the edges C, and the ends forming the cutting edges A A, should be turned up true in the lathe; the backing off may then be filed, leaving the cutting edges A with the turning marks barely effaced; thus they will be sure to be true and at an equal height from the end of the pin, so that both the cutting

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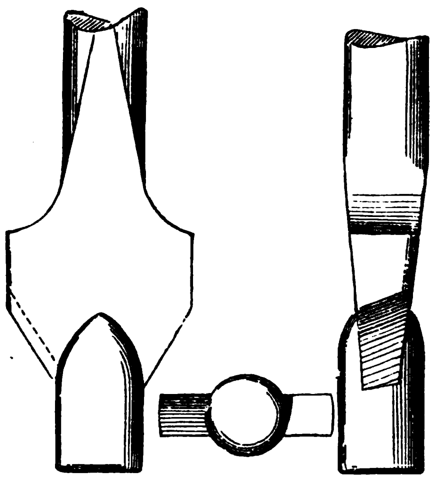
edges will perform duty, and not one only, as would be otherwise the case. Pin drills should be tempered to a deep straw color, and run at a comparatively slow speed, using oil for wrought-iron and steel, and running dry on cast-iron and brass. In cases where, for want of an assortment of pin drills, there is none at hand with a pin suitable for the size of hole required to be faced, a drill having one too small for the hole may be made up to the required size by placing upon it a ring of iron or brass of the requisite thickness and about equal in depth to the pin.

COUNTERSINK DRILLS.

Of countersinks, there are various forms; but before proceeding to describe them, it may be as well to observe that the pin drill described above may be employed as a flat-bottomed countersink. Fig. 80 represents a taper counter-

Fig. 80.



sink, such as is employed for holes to receive flush rivets or countersunk head bolts, this form of tool being mainly employed for holes above $\frac{5}{16}$ of an inch in diameter, A A

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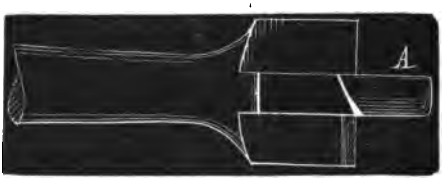
being in each case the cutting edge, and B the pin. It should be made, tempered, and used as directed for pin drills. In tempering these tools, or any others having a pin or projection to serve as a guide in a hole, the tool should be hardened right out from the end of the pin to about $\frac{3}{8}$ of an inch above the cutting edges. Then lower the temper of the metal (most at and near the cutting edges), leaving the pin of a light straw color, which may be accomplished by pouring a little oil upon it during the lowering or tempering process. The object of this is to preserve it as much as possible from the wear due to its friction against the sides of the hole. For use on wrought-iron and steel, this countersink (as also the pin drill) may have the front face hollowed out, after the fashion of the lip drill, and as shown in Fig. 60 at B.

For use on holes $\frac{1}{2}$ inch and less in diameter, we may use a countersink made by turning up a cone, and filing upon it teeth similar to those upon a reamer, or we may take the same turned cone and cut it away to half its diameter, similar to a half round bitt. Either of these countersinks will cut true and smoothly, oil being applied when they are used upon steel or wrought-iron.

Common drills, ground to the requisite angle or cone, are sometimes used as countersinks, but they are apt to cut

Fig. 81.



untrue and uneven. For fine and light work, the pin drill, with its cutting edges either at right angles to the centre line of the pin or at such other angle as may be required, forms the best countersink; it should, however, have more

than two cutting edges, so that they may steady it. Fig. 81 presents an excellent form of this tool, A being one of the four cutting edges.

This tool is formed by turning up the whole body, filing out the necessary four spaces between the cutters, and backing the latter off at the ends only, so that the circumferential edges will not cut, and hence the recesses or countersinks will be all of one diameter.

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CHAPTER XII.

TOOL STEEL.

THE cutting tools for all machines should be made of hammered (which is tougher and of finer grain than rolled) steel. Even in a bar of hammered steel, the corners, from receiving the most effect from the action of the hammer, are of better quality (that is, more refined) than the rest of the bar. This fact is clearly demonstrated in the manufacture of the celebrated Damascus swords and gun barrels, in which the square bars of metal are, after being hammered, twisted and then hammered square again; the twisting process is then repeated, and the bar again forged square, the whole operation being repeated until the body of the entire bar is completely intersected with metal which has, at some time during the forging process, formed the corners of a square. The effect of this treatment becomes apparent upon immersing the metal in acid, which will eat away those parts which have not formed a corner at some stage of the process of manufacture, more rapidly than the rest of the metal, and that to such a degree as to give to the whole the appearance of having been engraved, thus evidencing that the parts that have received the most hammering are of finer quality than the rest of the bar.

For cutting tools, it is highly necessary to gain every attainable superiority in the steel; and if we cannot take three months of time to prepare bars for this special purpose (as they do in the above process), we can at least employ well-hammered steel, and thus secure the best known practicable results.

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The test of tool steel is the speed at which it will cut and the length of time it will last without being ground, concerning which it is difficult to get data, unless by actual experiment with different kinds of steel upon work of the same diameter and texture of metal, because the cutting speed employed by workmen varies as much as 10 feet per minute upon the same diameter of work. The use of more than one kind of tool steel in a workshop should always be avoided, because different kinds of steel require different treatment, both in forging and hardening; and when more than one kind is in use in the shop, the whole of them are liable (from not noticing the particular brand) to wrong treatment.

Mushet's "special tool steel" makes an excellent tool for roughing work out on the lathe or planer, and will undoubtedly stand a higher rate of cutting speed than other steel. For turning shafting and cast-iron pulleys, especially when the latter are unusually hard, this tool works admirably. Its peculiarity is that it is hard of itself, and therefore requires no hardening. Immersing it in water when it is heated causes it to crack. The advantages claimed for it are its high rate of cutting speed, and that it is easily ground, since it will not soften by heating during the operation. It is, on the other hand, difficult to forge in consequence of its excessive hardness even when heated; it must not be forged at so great or so low a temperature as other steel, or it will crack; and as it is not adapted for general tool purposes, its disadvantages, independent of its increased cost, render its introduction into the *general* machine-shop unadvisable.

FORGING TOOLS.

The forging of a tool should be formed in as few heats as possible, for steel deteriorates by repeated heating, unless it is well hammered at each heat; and if the tool has a narrow edge, care should also be taken to hammer it on that edge before the metal has lost much of its heat,

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and to strike it more lightly as it gets cooler, for striking a narrow surface of steel when it is somewhat cool has the same injurious effect upon it as striking it endwise of the grain (which is termed upsetting it), destroying its cutting value and strength.

If the tool requires much drawing out, the steel should be drawn rectangular to as near as possible the required size, leaving only sufficient metal to shape up the tool. The steel should be heated to a light-red and in no case to a yellow heat, which would cause it to become what is termed "*burnt*," after which its cutting value is irretrievably lost, nor will any amount of forging restore it to its former standard. A tool that has been accidentally overheated should have the burnt part cut off and be entirely reforged. Front or other tools for use on wrought-iron should be forged as follows: Draw the bar steel down taper on one edge of the steel and parallel on the other, and then bend the cutting part of the tool up so that the tool will bear the shape of Figs. 1, 5, 14, and 19, which are better and more easily forged tools than those shown by Figs. 6, 10, and 11, the latter being *fac similes* of the forms of tools in use at the Morgan Iron Works. They are of perfectly correct form so far as the shapes of the cutting edges are concerned, but are more difficult to forge and to grind than the former, which are again superior in that the height of their cutting edges from the bottom edge is less, and hence they do not suffer so much from the causes explained by Figs. 14 and 15 and their accompanying remarks. It is obvious, however, that the height of the tool edge from the bottom face of a lathe tool is determined by the height of the face of the slide rest on which the tool rests from the horizontal centre of the lathe centres.

In using American chrome steel, be careful to forge it according to the directions supplied by its manufacturers, its treatment being almost the opposite for that applicable

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to English tool steel, the former requiring to be heated to a much higher temperature for forging, and to a less temperature for hardening, than the latter.

TOOL HARDENING AND TEMPERING.

Steel is said to be hardened when it is as hard as it is practicable to make it, and to be tempered when, after having been hardened, it is subjected to a less degree of heat, which partly but not altogether destroys or removes the hardness. The degree to which this tempering is performed, or in other words the degree of the temper, is made perceptible and estimated as follows: By heating a piece of steel to a red heat (not so hot as to cause it to scale), and then plunging it into cold water and allowing it to remain there until it is cold, it will be hardened right out, as it is termed, that is, it will be made hard to the greatest practicable degree. If it is then slowly reheated, its outer surface will, as the temperature increases, assume various shades of color, commencing with a very light straw color, which deepens successively to a deep yellow, red, brown, purple, blue, and green, which latter fades away as the steel becomes heated to redness again, when the effects of the first hardening will have been entirely removed. It becomes apparent, then, that the colors which appear upon the surface of the steel denote the degree to which the tempering or resoftening operation has taken place. Having then by practice ascertained the color which denotes the particular degree of hardness requisite for any specified tool, we are enabled to always temper it to that degree, sufficiently near for all practical purposes. It is undoubtedly true that, if the conditions of tempering which will be laid down in all our instructions are (for want of sufficient experience in the operator) varied, the colors will not present, to positive exactitude, the precise degree of temper: the difference being that, if the color forms very rapidly, the tool may be left of a lighter color; and that if

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the colors form very slowly, the tool may be left of a slightly deeper hue. The difference in temper, however, as compared to the color, will in no case be sufficient to be perceptible in ordinary tool practice, and need not, save under circumstances requiring great minuteness in the degree of temper, be paid any attention to.

When a tool such as a drill requires to be tempered at and near the cutting edge only, and it is desirable to leave the other part or parts soft, the tempering is performed by heating the steel for some little distance back from the cutting edge, and then immersing the cutting edge and about one-half of the rest of the steel, which is heated to as high a degree as a red heat, in the water until it is cold; then withdraw the tool and brighten the surface which has been immersed by rubbing it with a piece of soft stone (such as a piece of a worn-out grindstone) or a piece of coarse emery cloth, the object of brightening the surface being to cause the colors to show themselves distinctly. The instant this operation has been performed the brightened surface should be lightly brushed by switching the finger rapidly over it; for unless this is done, the colors appearing will be false colors, as will be found by neglecting this latter operation, in which case the steel after quenching will be of one color; and if then wiped, will appear of a different hue. A piece of waste or other material may of course be used in place of the hand. The heat of that part of the tool which has not been immersed will become imparted to that part which was hardened, and, by the deepening of the colors, denote the point of time at which it is necessary to again immerse the tool and quench it altogether cold.

The operation of the first dipping requires some little judgment and care; for if the tool is dipped a certain distance and held in that position without being moved till the end dipped is cold, and the tempering process is proceeded with, the colors from yellow to green will appear in

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a narrow band, and it will be impossible to directly perceive when the cutting edge is at the exact shade of color required; then again, the breadth of metal of any one degree of color will be so small that once grinding the tool will remove it and give us a cutting edge having a different degree of temper or of hardness. The first dipping should be performed thus: Lower the tool vertically into the water to about one-third of the distance to which it is red hot, hold it still for about sufficient time to cool the end immersed, then suddenly plunge it another third of the distance to which it is heated red, and withdraw it before it has had time to become more than half cooled. By this means the body of metal between the cutting edge and the part behind, which is still red hot, will be sufficiently long to cause the variation in the temperature of the tool end to be extended in a broad band, so that the band of yellow will extend some little distance before it deepens into a red; hence it will be easy to ascertain when the precise degree of color and of temper is obtained, when the tool may be entirely quenched. A further advantage to the credit of this plan of dipping is that the required degree of hardness will vary but very little in consequence of grinding the tool; and if the operation is carefully performed, the tool can be so tempered that, by the time the tool has lost the required degree of temper from being ground back, it will also require reforging or reforming. As a rule a tool should be made to a red heat to a distance about twice the diameter of the tool steel of which it is made.

The degree to which a tool may be hardened is dependent in a great measure upon its shape. The only reason for tempering any lathe tool is to strengthen it, for steel hardened right out is comparatively weak and gains strength by being tempered. The lower the temper the greater the strength. A straw color is well adapted to ordinary light tools, but very slight tools, such as say a parting tool $\frac{1}{16}$

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inch wide, may be lowered to a deep brown or almost to a purple. Stout tools, such as are shown in Fig. 6, may be made as hard as fire and water will make them; so also may the tools presented in Figs. 8, 9, 18, 19, 20, and 23; while slight tools, such as are given in Figs. 14 and 22, should be lowered in temper to a light straw color.

The practice of lowering stout tools to a straw color is sometimes resorted to, but it is certainly an error, for it is undoubtedly advantageous to make the tool as hard as it can be made, so long as it will bear the strain of the cut, which is possible and easy of accomplishment with Jessop's, Moss', Sanderson's, or other similar grades of tool steel.

If a tool so hardened is found to break, it is in consequence either of its being bad steel or else it has been heated to too great a temperature in the process of forging or hardening, unless it has been given too much rake for the duty to which it has been allotted. Tool steel may be forged at such a temperature that it is not positively burned, and yet has lost part of its virtue; and while under such circumstances it would break if hardened right out, it will cut and stand moderately well if the temper be lowered to a straw color.

This is simply sacrificing the degree of hardness to cover the blunder committed by overheating, and it is from such causes that the variation of cutting speed employed by mechanics arises; for a youth who has learned his trade in a shop where the tools were overheated, and consequently underhardened, settles down to the rate of cutting speed attainable under those circumstances and adheres to it; while he who has been accustomed to the use of tools properly forged and hardened right out, upon entering another shop where the tools are overheated in forging and underhardened to compensate for it, finding he cannot get the cutting speed up to his customary rate, breaks off the tool point to see if it has been burned, and, finding that the

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grain of the metal does not appear granulated, sparkling, and coarse, as it would do if positively burned, condemns the quality of the steel.

The grain of properly forged and hardened tool steel appears, when fractured, close and fine, and of a dull, whitish tint, the fracture being even on its surface.

American chrome tool steel may be made unusually hard by using very clean water and adding a piece of fuller's earth and a piece of common soda, each of the size of a hazel nut, to a pailful of water.

In all cases where a tool can be ground to sharpen it, it should be hardened before grinding, for steel hardened with the forged skin on is stronger and better than that in which the skin is removed before hardening. When it is intended to harden a tool right out, heat it to a cherry red to the distance that it is necessary to harden it, and plunge it into the water suddenly to the distance it requires hardening; hold it still a moment, then dip it a little deeper, and withdraw it again to the amount of the last dipping, repeating this latter operation until the tool is cold; for by this means the junction of the hard and soft steel in the tool is graduated and not sharply defined, the result being that the tool is less liable to fracture either in hardening or in using. If the tool to be hardened has a thick part to it, let that part enter the water first and immerse the tool slowly, so that it will be cooled as nearly equally as possible and thus be prevented from cracking in hardening.

Tools heated by charcoal are much superior to those heated by common coal, and need not be made quite so hot to harden. To harden steel, never get it hot enough to cause it to scale. Thin pieces of steel, and taps, dies, reamers, drifts, and similarly shaped tools, should be dipped endways; for if dipped otherwise, they are sure to warp in hardening. Very slight tools may be prevented from cracking by making the water quite warm before immersing them, and then holding them still in the water; in fact, all

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water for hardening purposes should have the chill off it by heating, before being used, or the articles hardened in it are very liable to crack. If the article requires to be hardened all over, immerse it (suspended on a wire hook) so that the water may have free and equal access to the whole surface of the steel, which is not possible with tongs in consequence of their jaws covering part of the steel.

HARDENING.

All work to be hardened should be heated according to its shape, the work being so manipulated in the fire that the thin parts do not get to the required heat before the thick parts do. Then in quenching them in the water the thick parts should be immersed first, and the operation be performed slowly. The work should be lowered perpendicularly in the water and immersed deeply, and not under any circumstances moved sideways. Uneven heating warps the work in the fire, careless dipping warps and cracks it in the hardening. Always use water that is at least lukewarm, and if the article has one part much thinner than another, or is very slight, and hence liable to warp or crack, make the water as hot as the hand will bear it, and dip the work edgeways, the heaviest side being downwards. Very small articles to be hardened in quantities may be heated in a piece of wrought-iron pipe, having one end closed, the pipe being revolved in the fire during the heating process to equalize the heating of the work.

TO HARDEN SPRINGS.

Small springs, which should be made of spring-steel or double-shear steel, may be hardened as follows: Heat them to a bright cherry-red, and quench them in water having the cold chill taken off it. If, on being taken from the water, they are white, or mottled with white and a light gray, they are hard enough, but if they are dark-colored, they are not hard enough, and must be rehard-

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ened. After being hardened, they may be tempered as follows: String them, if possible, on a wire, and fry them over the fire in a pan or tray containing enough lard oil to well cover them, and heat the oil until it will blaze all over the surface, then turn the springs over and over in the blazing oil, letting them blaze long enough to be sure that the thick parts of the spring are equally heated with the thin parts. If a single spring requires tempering, it may be tempered by fastening it to a wire, and just above it put a small roll of wire to retain the oil. Heat the spring over a very slow fire, and apply oil, letting it run down the wire to the spring. Keep the spring supplied with oil, and let it blaze a minute or so. If it has a light or thin part to it, pour cold oil on that part of it during the early part of the blazing process.

Large springs are first hardened, and then blazed off in whale oil, containing 2 lbs. of tallow and ¼ lb. of beeswax (or, instead of the latter, ½ lb. of black resin) to every gallon of whale oil. If a spring is made of cast-steel it must, after blazing off, be left to cool of itself without being quenched off.

Springs that have the forged skin on are stronger and more elastic than those which are brightened, and all springs are reduced in elasticity by grinding off the surface after they are tempered; especially, however, is this the case with those having the forged or rolled skin on.

To harden machine-steel, or make cast-steel very hard, put a pound of salt to a gallon of rain-water.

The longer water or a tempering liquid is used the better it becomes, but either of them are wholly spoiled if any greasy substance gets in them.

All steel, as well as iron, swells by hardening, so that holes become smaller, and outside surfaces larger, in consequence of hardening, and this fact is often taken advantage of to refit iron or steel work that has become worn. For instance, suppose a bolt has worn loose: the bolt may be

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hardened by the common prussiate of potash process, which will cause it to increase in size, both in length and diameter. The hole may be also hardened in the same way, which will decrease its diameter; and if the decrease is more than necessary, the hole may be ground or "lapped" out by means of a lap. Only about $\frac{1}{64}$ of an inch of shrinkage can be obtained on a hole and bolt by hardening, which, however, is highly advantageous when it is sufficient, because both the hole and the bolt will wear longer for being hardened.

CASE-HARDENING WROUGHT-IRON.

Iron may be case-hardened, that is, the surface converted into steel and hardened, as follows: First, by the common prussiate of potash process, which is as follows: Crush the potash to a powder, being careful that there are no lumps left in it, then heat the iron as hot as possible without causing it to scale; and with a piece of rod iron, spoon-shaped at the end, apply the prussiate of potash to the surface of the iron, rub it with the spoon end of the rod until it fuses and runs all over the article, which must then be placed in the fire again and slightly reheated, and then plunged into water, observing the rules given for immersing steel so as not to warp the article.

Another method is to place the pieces to be hardened in an iron box, made air-tight by having all its seams covered well with fire clay, filling the box in with bone dust closely packed around the articles, or (what is better) with leather and hoofs cut into pieces about an inch in size, adding thin layers of salt in the proportion of about 4 lbs. salt to 20 lbs. of leather and 15 lbs. of hoofs. In packing the articles in the box, be careful to so place them that when the hoofs, leather, etc., are burned away, and the pieces of iron in the box receive the weight of those above them, they will not be likely to bend from the pressure. When the articles are packed and the box ready to be closed with the lid, pour

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into it one gallon of urine to the above quantities of leather, etc.; then fasten down the lid and seal the seams outside well with clay. The box is then placed in a furnace and allowed to remain there for about 12 hours, when the articles are taken out and quickly immersed in water, care being taken to put them in the water endways to avoid warping them.

Articles to be case-hardened in the above manner should have pieces of sheet-iron fitted in them in all parts where they are required to fit well and are difficult to bend when cold. Suppose, for instance, it is a quadrant for a link motion: fit into the slot where the die works a piece of sheet-iron (say $\frac{1}{4}$ thick) at each end of the slot, and two other places at equidistant places in the slot, leaving on the pieces a projection to prevent them from falling through the slot. In packing the quadrant in the box, place it so that the sheet-iron pieces will have their projections uppermost; then, in taking the quadrant out of the box, handle it carefully, and the pieces of iron will remain where they were placed and prevent the quadrant from warping in cooling or while in the box (from the pressure of the pieces of work placed above it).

It is obvious, from what has been already said, that the heavier pieces of work should be placed in the bottom of the box.

TO CASE-HARDEN CAST-IRON.

In 3 gallons of clean water mix $\frac{1}{2}$ pint of oil of vitriol and 2 oz. of saltpetre. Heat the iron to a cherry-red and dip as usual.

TO HARDEN MALLEABLE-IRON.

Mix equal parts of common potash, saltpetre and sulphate of zinc, and use as directed for prussiate of potash.

THE CRYSTALLIZATION OF WROUGHT-IRON.

Crystallization will rapidly take place when wrought-iron is repeatedly heated without being well worked at

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each heat. Thus, apprentice blacksmiths will sometimes find a forging, which their want of skill in manipulating has caused them to heat and reheat without working the iron much, will jar off and break in pieces upon the anvil or upon using. Especially is this the case when the iron is of inferior quality, though it will occur with either low moor or Swedish iron. It would appear that unless the metal is so worked as to keep the fibre continuously moving, it loses its fibrous texture, and assumes a granular or crystallized texture, and to this fact is doubtless due the impracticability of forging very heavy solid wrought-iron ordnance.

Crystallization will rapidly ensue when wrought-iron is subject to blows delivered endwise of the grain; thus if a piece of cold bar-iron be stood up and struck repeated blows endwise of the grain, it will afterwards be found to break across the grain very easily; and, again, when a shaft has had to be cut shorter in the lathe so that there will be left a piece in the centre of, say, an inch in length and an inch in diameter, the machinist will find the iron offer the usual resistance to being cut off with the chipping-chisel, if cut across the grain; but if he nicks it around close up to the body of the shaft, and then strikes the end of the projecting piece sharp blows with a comparatively light hammer, it will usually break short off in the neck. A noticeable feature in this latter instance, however, is, that if the blows are delivered with a hammer sufficiently heavy, and the blows are sufficiently heavy to upset or rivet the metal of the projecting piece, it will usually rivet or burr outward and flatten outward without breaking off, but will split in all directions, each separate piece retaining its fibrous texture, and evidencing no tendency to crystallization, especially if the iron is of good quality, for crystallization takes place much more rapidly in inferior than in the better qualities of iron.

Another instance of crystallization through successive

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blows, especially those of a jarring nature, is to be found in the frequency with which the heads or the junction of the end of the thread and the body of the bolt beneath the nut, with which bolts upon trip or steam hammers will break. It may also be observed, that crystallization, by reason of sudden and repeated shocks to the metal, is greatly accelerated when the latter is at the same time subject to abrasion upon its exposed surface, as in the case of chain-links, which, from constant rubbing one against the other, will become almost bright, and the outer skin slightly hardened.

Rapid crystallization takes place when a piece of wrought-iron is subject to a degree of heat above that of the normal temperature of the atmosphere, although crystallization from this cause appears to be considerably retarded when rapid oxidization or corrosion on the surface of the metal takes place. The writer is also led to believe that crystallization from all these causes is considerably retarded when the shaft or bolt is a hollow and not a solid one.

Crystallization, from all these causes, save that of repeated heating without sufficiently working the metal by the blacksmith, appears to be entirely removed by the process of annealing, which is best performed by either a charcoal or a wood fire, the metal being allowed to cool in the ashes, and not made in the process of more than a blood-red heat.

A piece of iron that has been crystallized by repeated heating, and not being sufficiently worked by the blacksmith, so that it has what is commonly called "lost its virtue," may be recovered by heating it to nearly a white heat, and well working it with the hammer upon the anvil, especially if well drawn out in the direction lengthwise with the grain of the iron.

Steel of even the commonest grade does not appear to suffer from crystallization, except it be that due to overheating or successive heating without forging. Thus if a chipping-chisel after long service be broken in two, no evi-

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dence of crystallization will appear. Nor does decarbonized steel, or what is sometimes termed homogeneous iron, appear to crystallize under any conditions save under the above exception. If, however, the best cast-steel is once overheated, no ordinary amount of forging will restore it, as is evidenced by the fact that a turning tool once overheated, no matter how much it may subsequently be forged, will not perform a maximum of lathe duty.

Thus chains should be annealed whenever the surface of the links become bright from wear, and axles or shafts that suffer severe strains should be annealed when during the process of repairing it can be conveniently done.

THE WEAR OF METAL SURFACES.

The wear of metal surfaces, such as cast-iron, wrought-iron, steel, and brass, is governed as much by the conditions under which that wear takes place as it is by the degree of hardness of the metal.

It is a general rule, that motion in one continuous direction causes more wear, under equal conditions, than does a reciprocating motion, and also that the harder the metal the less the wear. To this latter rule there are, however, exceptions in favor of cast-iron, which will wear better when surrounded by steam than will any other metal. Thus, for instance, experience has demonstrated that piston-rings of cast-iron will wear smoother, better, and equally as long as those of steel, and longer than those of either wrought-iron or brass, whether the cylinder in which it works be composed of brass, steel, wrought-iron, or cast-iron—the latter being the more noteworthy, since two surfaces of the same metal do not, as a rule, wear or work well together. So also slide-valves of brass are not found to wear so long or so smoothly as those of cast-iron, let the metal of which the seating is composed be whatever it may; while, on the other hand, a cast-iron slide-valve will wear longer of itself, and cause less wear to its seat, if the latter is of cast-iron, than

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if of steel, wrought-iron, or brass. The duty in each of these cases is light; the pressure on the cast-iron, in the first instance cited, probably never exceeding a pressure of ten pounds per inch, while, in the latter case, two hundred pounds per square inch of area is probably the extreme limit under which slide-valves work; and what the result under much heavier pressures would be is entirely problematical.

Cast-iron in bearings or boxes is found to work exceedingly smoothly and well under light duty, provided the lubrication is perfect and the surfaces can be kept practically free from grit and dust. The reason of this is, that cast-iron, especially that of American manufacture, forms a hard surface-skin, when rubbed under a light pressure, and so long as the pressure is not sufficient to abrade this hard skin, it will wear bright and very smooth, becoming so hard that a scraper made as hard as fire and water will make it will scarcely cut the skin referred to. Thus, in making cast-iron and a wrought-iron surface, plates or planometers, we may rub two such plates of cast-iron together under moderate pressure for an indefinite length of time, and the tops of the scraper-marks will become bright and smooth, but will not wear off; while if we rub one of cast-iron and one of wrought-iron, or two of wrought-iron, well together, the wrought-iron surfaces will abrade so that the protruding scraper-marks will entirely disappear, while the slight amount of lubrication placed between such surfaces to prevent them from cutting will become, in consequence of the presence of the wrought-iron, thick and of a dark-blue color, and will cling to the surfaces, so that after a time it becomes difficult to move the one surface upon the other. If, however, the surfaces are pressed together sufficiently to abrade the hard skin from the cast-iron, a rapid cutting immediately takes place, which is very difficult to remove, the only remedy being to entirely remove the particles of metal due to the abrasion, and lubricate very freely.

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Under a light duty, cast-iron, especially when working under steam pressure, will wear longer and better than brass, wrought-iron or steel, even if the motion be continuously in one direction; thus, for revolving side-surfaces, such as discs, it retains its superiority over the harder metals, and there is no test so great as is involved under such conditions, for the following reasons:

Suppose we have a piston revolving in a cylinder. The metal on the piston, at a distance of 2 inches from its centre, will pass over a circle, in the cylinder, of 12,566 inches in circumference. The metal on the piston, however, at a distance of 4 inches from its centre, will pass over a circle or surface of a circumference of 25,132 inches. Thus, we find the one part of the piston to pass over twice as much metal as does the other in performing a revolution, making the wear on *that* account twice as great at the large radius as it is at the small one. But this is not all, for the metal at the large radius travelled over its wearing surface, that is to say, the surface it bears against, in making a revolution, at a speed twice as great as did the metal at the small one over its wearing surface, since one travelled over sixteen inches in the same time that the other travelled over eight inches of surface; this increase further doubles the wear at the large radius, making its wear fourfold that at the small one, and giving us the rule that the wear of a revolving disc increases (as does its area) in the ratio of the square of its diameter. The result of this inequality of wear was demonstrated in the early days of locomotive-engineering, at which time the throttle-valves were in nearly all engines semi-revolving discs, with radial openings, the wearing surfaces being on the side face, and the disc revolving reciprocally on a centre-pin.

The result of the wear on such valves was found to be very unsatisfactory, because the metal at and near the extreme circumference would wear very rapidly away. The pressure of the steam, however, by springing the outer

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surface of the disc to its seat, would prevent the faces from leaking, but the pressure of the outer diametrical surface to its seat would be diminished in proportion to the resistance of the metal to the spring referred to, and, as a consequence, the surface of the metal at and near the centre of the disc would have upon its bearing surface not only the pressure due to the steam acting upon its exposed surface, but an amount in excess equal to that to which the outer diameter was relieved in consequence of its resistance to spring.

These conditions would continue until the wear of the larger diameter becoming greater, and the amount of spring required to keep it to its seat increasing in proportion, the resistance of the metal to so much spring partly relieves the pressure of the larger diameter to its seat, and since the pressure due to the force exerted by the steam upon the exposed surface of the disc will remain constant, to whatever amount the outer diameter is relieved of the pressure to its seat, that at and near the centre, forcing it to its seat, will be augmented, until at last the excessive pressure will cause it to cut or abrade, which action will continue until the cutting at and about the centre will allow the larger diameter to bed with more force to its seat, by diminishing the amount of its spring, and hence its resistance to the steam-pressure immediately behind it, whereupon its excessive wear would recommence.

If, however, the thickness of the disc were made such as to enable it to resist the steam-pressure without springing, the larger diameter would wear sufficiently away to cause the valve to leak; whereas, if the disc were made sufficiently thin to enable it to spring easily, the outer diameter would wear to almost a feather-edge, while the metal about the centre would nearly maintain its original thickness.

It is this inequality of wear in revolving, or side, or disc surfaces that is the stumbling-block to the success of rotary engines, nor has there as yet been suggested any method of overcoming or compensating for it. It is difficult, indeed,

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to perceive in what direction such a remedy can lay, unless it be in making the disc of hardened steel and tempering it, so that being at the outer diameter as hard as fire and water will make it, it is so tempered that it shall be gradually softer as the diameter decreases, until at the centre it is quite soft. Thus the degree of hardness of the metal will be as far as possible in proportion to its liability to wear.

In an experiment made by me, I revolved two cast-iron disc-surfaces, of three inches diameter, under a pressure of steam of 20, 35, and 70 lbs. alternately, per square inch, the surface being pressed together under a pressure of about 7 lbs. per square inch, and the discs making three thousand revolutions per minute. I found that, in consequence of the light pressure, forcing the faces together, a cast-iron surface showed but very little signs of wear—not sufficient, indeed, after running ten hours a day for ten days, to efface the scraper-marks from the surfaces, which had become polished and glazed, as it were. Several small holes were then drilled in the contacting surfaces, and plugs of Babbitt metal, brass, wrought-iron, and steel, were inserted, the faces being rescraped all over, and the discs then run as before, the result being that, after two days of running, the cast-iron appeared smooth and bright as before, while the brass, wrought-iron, steel, and Babbitt metal were found to be worn positively below the surface of the cast-iron, several repetitions of the last experiment giving, in each case, a like result.

The reason that the liability to cut is found in practice to be much greater in revolving than in reciprocating surfaces is that, when a revolving surface commences to cut, the particles of metal being cut are forced into and add themselves, in a great measure, to the particles performing the cutting, increasing its size and the strain of contact of the surfaces, causing them to cut deeper and deeper until at least an entire revolution has been made, when the severed

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particles of metal release themselves, and are for the most part forced into the grooves made by the cutting.

In reciprocating surfaces, when any part commences to cut, the edge of the protruding cutting part is abraded by the return stroke, which fact is clearly demonstrated in either fitting or grinding in the plugs of cocks, in which operation it is found absolutely necessary to revolve the plugs back and forth, to prevent the cutting which inevitably and invariably takes place if the plug is revolved in a continuous direction. Furthermore, when a surface revolves in a continuous direction, any grit that may lodge in a speck, hollow spot, or soft place in the metal, will cut a groove and not easily work its way out, as is demonstrated in polishing work in a lathe; for be the polishing material as fine as it may, it will not polish so smoothly unless kept in rapid motion back and forth. Grain emery used upon a side-face, such as the outer face of a cylinder-cover, will lodge in any small, hollow spots in the metal and cut grooves, unless the polishing stick be moved rapidly back and forth between the centre and the outer diameter. If a revolving surface abrades so much as to seize and come to a standstill, it will be found very difficult to force it forward, while it will be comparatively easy to move it backward, which will not only release the particles of metal already severed from the main body, and permit them to lodge in the grooves due to the cutting, but will also dislodge the projecting particles which are performing the cutting, so that a few reciprocating movements and ample lubrication will, in most cases, stop the cutting and wash out the particles already cut from the surfaces of the metal.

It is held by many that fast-running bearings filled with Babbitt metal will wear better than brass bearings. Such, however, is not the case, if the bearings are properly fitted; the only advantage possessed by Babbitt metal bearings is that they are more easily fitted; because the Babbitt will run so as to make an even and equal bearing upon the

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shaft, and it is therefore only necessary to set the shaft true before pouring the metal, to insure an even and true bearing; whereas, after the brasses are fitted and bored, they require fitting to the shaft while in their places, and this being a somewhat tedious operation is often omitted, the consequence being that the journal does not bed fairly on the bearing surface, and thus the whole strain of the bearing is placed upon the reduced surface of the brasses which beds upon the journals, and the increase of journal-pressure per inch, placed upon the brass, induces undue abrasion, and a consequent rough surface tending to produce continuous abrasion and heating. In bearings of this kind, the boxes or bearings should be of hard composition, as, say, a mixture of 12 parts of copper to 1½ of tin, and ½ of zinc, which will turn in the lathe easily, and yet be sufficiently hard to resist abrasion under ordinary duty.

ANNEALING OR SOFTENING.

To soften finished iron or steel work without damaging its finish, well lute an iron box with fire-clay, and place the work in it, surrounded by turnings or borings of the same metal as itself. Fill the box full of such turnings, place the lid on, and lute it with fire-clay; then place it in a furnace, heat slowly to a red heat, and allow the furnace fire to go out and the box to cool in the furnace.

To anneal electro-magnets, first heat the iron to a very low red heat, and let it cool off in soft soap; then reheat to a low red, and let it cool while well covered in slaked lime.

To anneal ordinary steel, heat it to a low red heat and allow it to cool in ashes or lime.

To remove the sand and scale from iron castings, immerse them in a pickle composed of one part oil of vitriol to three parts of water. In six to ten hours remove and wash them with clean water; when time is no object, make the solution weaker, and let them pickle longer.

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MIXTURES OF METALS.

Babbitt metal bearings for fast running journals—Tin, 50 parts; antimony, 5 parts; copper, 1½ parts.

Brass for journal boxes—Copper, 10 pounds; tin, 1½ pounds; spelter, ½ pound.

Brass for valves—Copper, 9 pounds; tin, 1 pound; spelter, ¼ pound.

Bell metal—Copper, 50 pounds; tin, 11 pounds.

Yellow brass—Copper, 20; zinc, 10 pounds; lead, ¼ pound.

Yellow brass for castings—Copper, 36 parts; zinc, 17 parts; lead, 2½ parts; tin, 2½ parts. The zinc to be added last to prevent its burning away.

Gun metal—Copper, 9 parts; tin, 1 part.

Solders—Fine, tin 1 part, lead 1 part. Plumbers, tin 1 part, lead 2 parts. For cast-iron, tin 2 parts, lead 1 part.

Soldering liquid—Muriatic acid which has dissolved scraps of zinc until sponge zinc will form in it, is fit for soldering brass or copper work; for cast or wrought-iron work, sal-ammoniac should be added; while for tin, the latter may be omitted, and water, in the proportion of one-third, added.

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CHAPTER XIII.

TAPS AND DIES.

TAPS should be forged of hammered square bar steel, and forged to as near the finished size as possible (so that they are large enough to true up), because the metal on the outer surface of a forging is, from receiving the most of the effects of the forging, of finer quality than the interior metal. After the forging of the tap is complete, it should be heated to a low red heat and covered in lime or ashes, the object being not only to soften the metal and make it easier to cut, but to release any tension there may be upon the outer skin, in consequence of the forging, for there is a tension upon the surface of all forged as well as cast work.

The effect of blows delivered upon forged work by the blacksmith's tools is not only greater upon the exterior than upon the interior of the metal, but is greatest upon that part of the forging which receives the most working, and upon that part which is at the lowest temperature during the finishing process: because the blows delivered during the finishing process are lighter than those during the earlier stages of the forging, and hence their effects do not penetrate so deeply into the body of the metal. Then again, on that part of the metal which is coolest, the effects of the light hammering do not penetrate so deeply; and from these combined causes, the tension is not equally distributed over the whole surface of the forging, and hence its removal, by cutting away the outer surface of any one part, and thus releasing the tension of that part, alters the form of the whole body, which does not, therefore, assume its normal shape until the outer skin of its whole surface

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has been removed. While the metal is at about an even heat all over, and is above a red heat, the effect of working the metal by forging it is simply, as already stated, to improve its texture, to close the grain, and thus to better its quality, especially toward and at its outer surface; but as the tension commences, while and after the metal loses its redness, we adopt the plan, after forging, to heat the tap all over to a low red heat, and to then lightly file its surface so as to remove any protruding scale; then allow it to cool of itself, without any forging being performed upon it at that heat. This process will nearly, if not entirely, remove the tension created by the forging.

If the tap is a long one, many experienced blacksmiths state that it should, after the forging is completed and the tap is very nearly or quite cold, be stood endwise on the anvil, and placing a flatter on the end of the tap, strike the flatter a sharp blow with a light sledge, which it is stated will set the metal so that it will not warp in the process of hardening. An excellent plan to effect the same object is to rough out the tap all over, so as to remove the tension, and to then heat the tap to a low red, and allow it to cool gradually.

The threads of taps of the smaller sizes should be finished by a chaser, so as to insure correctness in the angles and in the depth of the thread.

The taper tap should not be given more taper than the depth of the thread in the length of the tap, or it is liable to be used on holes that are too small, which places more duty upon it than is necessary and than it should be required to perform; rendering it, in consequence, liable to break from the excessive strain, and causing the square end of the tap, where the wrench fits, to twist and the corners to become rounded.

A tap which has much clearance placed upon its thread, by the screw-cutting tool, or by a chaser, will cut very freely, and will answer for rough work; but such a

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tap does not cut a really good thread, and generally leaves the diameter of the thread in the hole larger than the diameter of the tap itself, because the tap is liable to wabble, and the least excess of pressure, on one end of the tap wrench more than on the other, causes the tap to lean towards the end of the wrench receiving the most pressure, and hence, to tap a hole larger than itself. Especially is this liable to occur if the tap wrench has more than one square hole in it so as to enable the same wrench to be used on more than one size of tap; for in such a case, the holes being not in the centre of the wrench, the weight of the wrench and the pressure placed on the end of the wrench will exert more pressure on one side of the tap than the other, in consequence of their greater distance or longer leverage from the tap. The same effects (from the use of such wrenches) are experienced in using taps having no clearance in the thread; but the thread in this latter case is so much nearer a fit to the hole that it serves as a guide and keeps the tap steady.

Fig. 82.

Then, again, if a tap has much clearance upon the thread, and is required to back out from and not pass entirely through the thread, the cuttings jam between the thread in the hole and the thread upon the tap, especially if the hole is in cast-iron. The sides of the teeth of such a tap have a very small bearing upon the sides of the thread in the hole, causing the tap, if used by hand, to work very unsteadily.

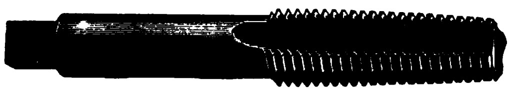
Taps for use in machines, such as the nut tap shown in Fig. 82, which is of the pattern made by H. S. Manning & Co., may have considerable clearance in the thread, the greater part of which clearance should be at the back end of the teeth.

Taps for ordinary work may have a very slight amount of clearance placed upon the teeth back from the cutting edge, just sufficient in fact to prevent them from binding *hard* against the sides of the thread being cut, and yet not sufficient to prevent the sides of the teeth from acting as a guide to steady the tap in the hole being threaded or tapped. Taps for holes requiring to be unusually exact in their diameter should not have any clearance placed upon the sides of the thread, but may have a flat place filed along the tops of each row of teeth, the flat face terminating close to the flute on either side of the length of the teeth, but in no case extending entirely to the flute. The flute of a tap should be volute and not carried over the back end of the teeth, otherwise the cuttings are apt to jam when the tap is being backed out.

If the flute of a tap is made spiral, it serves to steady the tap in the hole, especially if the latter is not round; but the extra trouble involved in making spiral flutes has prevented their universal application.

The taps shown in Fig. 83 are of H. S. Manning's pattern,

Fig. 83.



TAPER.

PLUG.

and are much superior to those formerly made by the New York tap and die company, because the amount of clearance in the thread has been greatly reduced.

The taper tap, for very fine work, should however be

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turned parallel the same as a plug tap, and then have the taper made by turning off the thread to a straight taper which just turns the thread out at the entering end of the tap, and leaves about four full threads at the end of the tap thread; and such a tap will work much more steadily than one having more thread on the taper end.

Taps having thread on the small end of the taper tap do not cut a correct angle of thread at starting, and gradually right themselves as the tap enters, the reason for which will be found illustrated in Fig. 85, and in the remarks upon adjustable screw dies.

The plain part of a tap, that is, that part from the thread to the end of the square where the wrench fits, should be turned down a little smaller in diameter than the bottom of the thread (unless in the case of very small taps), so that the tap can pass right through the hole in all cases where the hole passes through the work, thus saving time by obviating the necessity of winding the tap back, and furthermore preserving the cutting edges of the tap teeth by avoiding the abrasion caused by their being rubbed backwards against the metal of the hole. For special work, where the holes to be tapped do not pass through the work, and it is therefore compulsory to wind the tap backwards to take it out of the hole, the plain part of the tap may be left larger than the diameter of the thread, the advantage being that the squares of several different sizes of taps may be made alike, and therefore to suit one tap wrench.

Taps for use in holes to be tapped deeply should be made slightly larger in diameter than those used to tap shallow ones, because in deep holes the tap is held steady by its depth in the hole, and because whatever variation there may be in the pitch of the threads in the hole and those on the bolt, is, of course, experienced to an extent greater as the length of the thread (that is, the number of threads) increases.

It is an excellent plan to finish the threads of a tap by

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passing it through a sizing die, that is, a solid die kept for that special purpose; but very little metal must be left on the tap for the solid die to take off, or it will soon wear and get larger. In making such a solid die, let its thickness be rather more than the diameter of the tap it is intended to cut, and make allowance for its shrinkage in hardening, for all holes shrink in hardening, while taps swell or become larger from that process; an allowance for this must therefore be made both in the case of the tap and the die. In the case of the solid die, it will be found that not only does the hole become smaller, but the external dimensions of the entire die have become larger by reason of the hardening, so that while the term shrinkage is correct, as applied to the hole, it is incorrect as applied to the die, the fact being that the metal of the die (the same as the metal of the tap) has expanded, extending its dimensions in all directions, and therefore in the direction of the centre of the hole, hence causing a decrease in its diameter or bore.

Three flutes are all that are necessary to small taps (that is, those up to about half an inch in diameter), which leave the tap stronger and less liable to wabble, especially in holes that are not round, than if it had four flutes. Taps of a larger size may have more flutes, but the number should always be an odd one, so that the tap will do its work steadily.

The United States standard for threads, which was first adopted by the Franklin Institute, is as follows:

DIAMETER OF TAP.

$\frac{1}{4}$	$\frac{5}{6}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	2

NUMBER OF THREADS TO INCH.

20	18	16	14	13	12	11	10	9	8	7	7	6	6	$5\frac{1}{2}$	5	5	$4\frac{1}{2}$

In this standard, the screw threads are formed with straight sides at an angle of sixty degrees to each other,

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having a flat surface at the top and bottom equal to one-eighth of the pitch, the pitches as above.

The English or Whitworth standard varies from the above both in shape and number of threads to inch, as below:

DIAMETER OF TAP.

$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	2

NUMBER OF THREADS TO INCH.

20	18	16	14	12	11	10	9	8	7	7	6	6	5	5	$4\frac{1}{2}$	$4\frac{1}{2}$

In this standard, the screw threads are formed with flat sides at an angle of fifty-five degrees to each other, with a rounded top and bottom. The proportions for the rounded top and bottom are obtained by dividing the depth of a sharp thread having sides at an angle of fifty-five degrees, into six equal parts, and within the lines formed by the sides of the thread, and the top and bottom dividing lines inscribing a circle, which determines the form of top and bottom of thread.

Taps should be heated, for hardening, in a charcoal fire, and be heated slowly to a cherry red, and then dipped perpendicularly into clean water. The water should be made sufficiently warm to feel pleasant to the hand; for, if the water has not the cold chill taken off it, the taps are apt to crack along the flutes. The tap should be lowered perpendicularly in the water, even after it has disappeared below the surface; but in no case should it be moved sideways, or it will warp. It should not be taken out of the water until quite cold, or it will crack after it is taken from the water and during the cooling process. After the tap is hardened, it should be brightened along the flutes and on the plain part, and then lowered, as follows: A piece of tube, about half the length of the tap, and of about twice or three times its diameter, and having its thickness about the same, if possible, as the diameter of the tap, should be

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heated in the fire to an even cherry-red heat, and then taken from the fire and placed in such a position that it is open to clear daylight and not affected by the rays of light from the fire.

The tap should be held in a pair of tongs, whose jaws have been well warmed; and a small piece of metal should be interposed between the jaws of the tongs and the sides of the square of the wrench-end of the tap, so that the tongs may not obstruct the square of the tap from receiving the heat from the tube. The tap and tongs should then be passed through the heated tube, so that the square end of the tap and the tongs only will be inside the tube. The tap should be slowly revolved while in this position; and when the tap has at that end become slightly heated, but not enough to draw the color, the shank and threaded part of the tap should then be slowly passed endways back and forth, and, while slowly revolving through and through the centre of the tube, until the color appears, and if it appears of an even hue all over, proceed until a brown color appears; then withdraw the tap from the tube and quench it perpendicularly in warm water. If, however, the color does not not appear so quickly in any particular part, hold that part in the tube a little the longest, and if either end lowers too rapidly, cool it by a slight application of oil. The square end of the tap, on which the wrench fits, may be lowered to a deeper color, as may also the shank of the tap, than the threaded part, which will leave them stronger and less liable to twist or break. By using the size of tube here recommended, it will be found that the tempering process will be performed, and the colors appear very slowly, so that there will be ample time to judge when the precise requisite degree of hardness has been reached. This plan is far superior to tempering in heated sand. Very long taps may be greased and heated preparatory to being hardened in molten lead, the object being to heat the outside of the tap evenly all over to a red heat so rapidly that the inside

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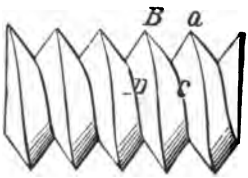
metal of the tap is comparatively cool, hence, when the tap is hardened, the outside only is hardened; and, if the tap warps in the hardening, it can, after being tempered, be straightened, the soft metal of the centre of tap preventing it from breaking in the straightening, which should be performed with a leaden hammer, and with the tap resting upon lead.

ADJUSTABLE DIES,

That is, those which take more than one cut to make a full thread, should never be used in cases where a solid die will answer the purpose, because adjustable dies take every cut at a different angle to the centre line of the bolt, as explained by Figs. 84 and 85.

Fig. 84 represents an ordinary screw. It is evident that the pitch from *a* to B is the same as from C to D, the one being the top, the other the bottom, of the thread. It is also evident that a piece of cord, wound once around the top of the thread, will be longer than one wound once around the bottom of the thread, and yet, in passing once around the thread, the latter advanced as much forward as the former, that is, to the amount of the pitch of the thread. To illustrate this fact, let *a b*, in Fig. 85, represent the centre-line of the bolt lengthwise, and *c d* a line at right angles to it: then let from the point *e*, to the point *f*, represent the circumference of the top of the thread, and from *e* to *g*, the circumference of the bottom of the thread, the lines *h h* representing their respective pitches; and we have the line *k*, as representing the angle of the top of the thread to the centre line *a b*, of the bolt, and the line *l*, as representing the angle of the bottom of the thread to the centre-line *a b*, of the bolt, from which it becomes apparent that the top and the bottom of the thread are at different angles to the centre line of the bolt.

Fig. 84.



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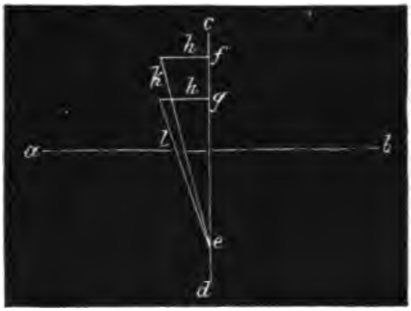
The tops of the teeth of adjustable dies are themselves at the greatest angle, while they commence to cut the thread on the bolt at its largest diameter, where it possesses the

Fig. 85.



least angle, so that the dies cut a wrong angle at first, and gradually approach the correct angle as they cut the depth of the thread.

From what has been already said, it will be perceived that the angle of thread, cut by the first cuts taken by adjustable dies, is neither that of the teeth of the dies nor that required by the bolt, so that the dies cannot cut clean because the teeth do not fit the grooves they cut, and drag in consequence.

DIES FOR USE IN HAND STOCKS

are cut from hubs of a larger diameter than the size of bolt the dies are intended to cut; this being done to cause the dies to cut at the cutting edges of the teeth which are at or near the centre of each die, so that the threads on each side of each die act as guides to steady the dies, and prevent them from wabbling as they otherwise would do; the result of this is, that the angle in the thread in the dies is not the correct angle for the thread of the bolt, even when the dies are the closest together, and hence taking the finishing cuts on the thread, although the dies are

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nearer the correct angle when in that position than in any other. A very little practice at cutting threads with stocks and dies will demonstrate that the tops of the threads on a bolt, cut by them, are larger than was the diameter of the bolt, before the thread was commenced to be cut, which arises from the pressure, placed on the sides of the thread of the bolt, by the sides of the thread on the dies, in consequence of the difference in their angles; which pressure compresses the sides of the bolt thread (the metal being softer than that of the dies) and causes a corresponding increase in its diameter. It is in consequence of the variation of angle in adjustable dies that a square thread cannot be cut by them, and that they do not cut a good V thread.

In the case of a solid die, the teeth or threads are cut by a hub the correct size, and they therefore stand at the proper angle; furthermore, each diameter in the depth of the teeth of the die cuts the corresponding diameter on the bolt, so that there is no strain upon the sides of the thread save that due to the force necessary to cut the metal of the bolt thread.

In a taper tap, whether it have a V thread or a square one, each individual diameter and angle of thread cuts the same diameter and angle in the hole, providing the bottom of the thread is of the same diameter all along the tap, and that the taper is made by turning off the tops of the threads; if, however, the tap is made taper and the thread is cut taper, the angles of the sides of the thread itself will not stand true with the diameter of the body of the bolt or tap, nor will the angle of the thread stand true with the centre line of the length of the bolt.

A solid die, having the teeth tapered off so that at the entrance there will be the bottom of the thread only and a full thread will not have been reached until the bolt has entered the die to a distance equal to five or six times the amount of the pitch of the thread, will cut a moder-

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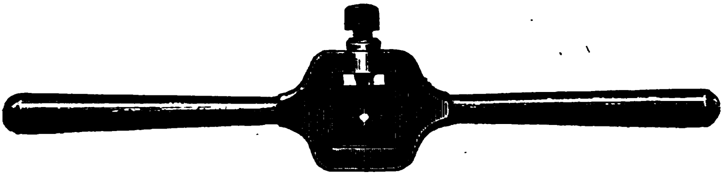
ately good square thread, but such dies take a great deal of power to drive them.

In making dies, whether they are adjustable or not, it is of the utmost importance that the recesses, or spaces cut to form the cutting edge of the teeth, be roomy, so that the cuttings will pass easily away and not clog in the die, as is too commonly the case. The teeth of a die may be given a little top rake.

Fig. 86 represents a pair of stocks and dies of the pat-

Fig. 86.



tern sold by H. S. Manning, there being to each pair of stock dies from $\frac{1}{8}$ to $\frac{1}{4}$, inclusive, by 32ds. Similar stocks with keys instead of pins, and containing dies up to $1\frac{1}{8}$ inches, are supplied by the same firm. For the smaller sizes of taps—that is to say, to $\frac{3}{4}$ inch—the adjustable tap wrenches, shown in Fig. 87, are supplied by the same firm,

Fig. 87.

and they are an excellent tool. Care, however, should be taken, in using them, to screw them up to fit the squares of the tap.

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CHAPTER XIV.

VISE WORK—TOOLS.

THE tools used by the vise hand being nearly all supplied to him ready made, but few remarks need to be made to him upon the subject of their form.

CALIPERS.

Outside calipers, that is, those used for measuring external diameters, should have larger rivets in them than they are generally given, a fair proportion being a rivet of one-half inch diameter for a pair of calipers intended to measure up to diameters of seven inches. The points of such calipers should be tapered to a wedge shape, the tapering face being on the outside edge, so that the same part of the points of each leg will touch the work, whether the latter is of small or large diameter; the points, where they meet together, should be slightly rounding, so that they will touch the work at the middle of each point.

For use on threads, the points must either be made very broad, and come together level and even, so as to gauge the tops of the thread, or be made very thin, to gauge the bottom of the thread. The legs of inside calipers should be eased away on each side close to the washers, and the points should—for calipers, say eight inches long—be about ¼ inch long and be straight and not curved, standing at an angle of about 45°, which enables the calipers to have a large rivet and washer, and to enter a smaller hole, and clear a longer distance, than is possible where the points are bent round in the manner commonly employed.

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Another feature to the advantage of this form is, that when the legs are extended, the points are still at the extreme end of the calipers, so that the points will measure to the extreme end of the hole, even though the latter is closed by metal, that is, terminates in the metal. This is not the case when the caliper ends are bent round to the usual extent, for the curve of the bend will touch the end of the hole and prevent the caliper points from reaching it. In measuring with calipers, let the points be set to touch the work very lightly indeed, or they will spring from the pressure due to forcing them over the work.

Compass calipers should have the end of one leg bent round at the end, about the same as is customary for inside calipers, the other leg being pointed like a compass leg. They are valuable tools, and may be employed to mark off the centres of holes, or to try if a centre already existing is in the exact centre of the hole. Or they will mark off a face, so that it will fit another face, whether it be regular or irregular, the curved point being kept against the irregular face, and the point describing (by moving the compass along) a similar line on the face to be fitted. They will answer for many of the uses to which a scribing block is put; and being lighter and more easily handled, and, furthermore, capable of doing duty without the use of a surface or scribing plate, they are in such cases far preferable.

The legs may be crossed so that the curved point inclines to the straight point, in which position they will mark the centres of shafts or rods, either round, square, or any other shape, or try such centres, when they already exist, more accurately than can be done by any other tool. They will, in this case, mark off a line at the distance to which they are set round any surface; they are employed to mark off keyways, or the taper of a gib when the key and one edge of the gib is placed, and for a variety of other uses too numerous to recapitulate, being among the most useful tools the fitter can possibly possess. The points of calipers

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should be tempered to a blue, and of compass calipers to a straw color.

THE SQUARE.

The square is too common a tool to require any description of its form. The best method to make one is to make the back of steel, and in two halves, one-half being the thickness of the blade thicker than the other. The slot for the blade must then be filed in the thickest half, to the depth exactly equal to the thickness of the blade. The two halves composing the back must then be riveted together, and the edges surfaced each true of itself (using a surface plate to try them), and also true with each other. The blade, which should be made of saw blade, may then be put into its place, ready to have the holes for the rivets drilled. It should be placed so that the outer end is a little depressed (on the inside angle) from the right angle; this is done so that whatever there may be to take off the blade (after it is riveted to the back), to make its edges form right angles to the back, will require to be taken off the outer end of the inside angle and the end of the blade forming the corner of the outside angle, so that no work will require performing on the blade in the corner formed by the blade entering the back on the inside angle, where it would be difficult to file or scrape without injuring the edge surface of the back. The best way to true a square is to turn up a piece of round iron equal in length to the square blade, being careful to make it quite parallel, and then true up the end of the iron, making it hollow towards the centre, or cutting it away from the centre to within an eighth of an inch of its diameter, so that it will stand steadily on its end. If the piece of iron be then stood on its end on a surface plate, its outline on each side, which represents its diameter, will form a true right angle to the surface of the plate, and hence a gauge with which to true the square.

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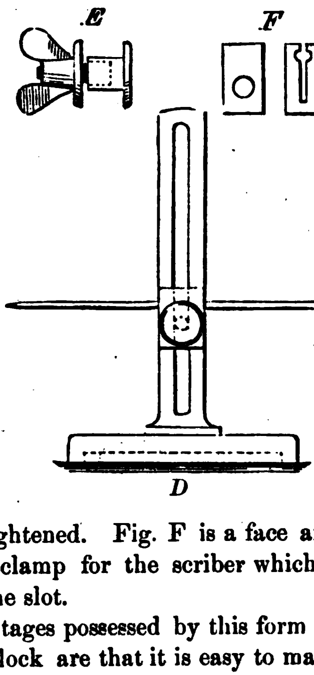
THE SCRIBING BLOCK.

This tool is made in a variety of forms, but the simplest and best form is that shown in Fig. 88, in which D is the block complete, the scriber being a simple piece of round steel wire. The dotted line on the foot is the distance to which the foot is hollowed out to make it stand firm. Fig. E is the bolt and nut; the bolt has a flat side filed on each side of it to fit it to the slot in the scribing block stem, so that the bolt cannot turn when

Fig. 88.



it is being tightened. Fig. F is a face and edge view of the piece or clamp for the scriber which passes through the hole in the slot.

The advantages possessed by this form over other forms of scribing block are that it is easy to make, and that the scriber, being a piece of wire, is easily renewed. It holds the scriber very firmly indeed, and the scriber may be moved back and forth without the nut becoming slack, an

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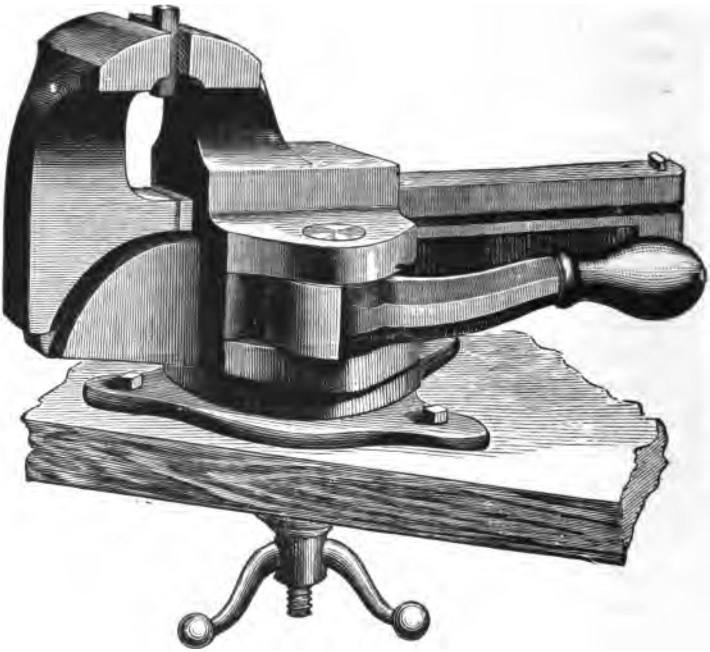
object of great importance not attainable in the common form of this tool.

The vise represented in Fig. 89 is of the Stephens' pattern. It is a substantial tool, and from the quick-

Fig. 89.



ness with which it can be moved and locked, and the firmness of its grip, is a desirable tool.

CHIPPING.

The chisel requires special notice, since it is frequently made of the most ill-advised shape (for either cutting smoothly or standing the effects of the blow), that is, hollow as in Fig. 90, in which case there are two sections of

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metal, represented by the dotted lines *a a*, which are very liable to break, from their weakness and from the strain outwards placed upon them by the cut, which, acting as a wedge, endeavors at each blow to drive them outwards instead of inwards, as would be the case in a properly shaped chisel, as shown in Fig. 91; *a* being the cutting

Fig. 90.

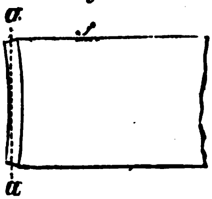
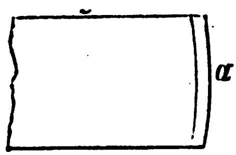


Fig. 91.



edge. All chipping chisels should be kept thin at their cutting ends, which saves both time and labor in their use.

When using, hold it firmly against the cut, and it will do its work smoother and quicker.

The cape, or, as it is sometimes called, cross-cut chisel, is employed to cut furrows across the work to be chipped, which furrows, being cut at a distance from each other less in width than the breadth of the flat chisel, relieve the flat chisel and prevent its corners from "digging in" and breaking. If a large body of metal requires to be chipped off cast-iron or brass, the use of the cape chisel becomes especially advantageous, for the metal, being weakened by the furrows, will break away in pieces from the force of the blow, without requiring to be positively cut by the chisel; but care must be taken to leave sufficient metal to take a clean finishing cut, for when the metal is broken away, by the force of the blow, it is apt to break out below the level of the cut. It is also necessary to nick deeply with a chisel the outside edges of the work at the line representing the depth of the metal to be chipped off, so that the metal shall not break away at the edges deeper than the cut is intended to be.

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A hand-chipping hammer should not weigh more than $1\frac{3}{4}$ lbs., and should be of the forms shown in Fig. 92; which pattern is kept, in various sizes, by H. S. Manning & Co. The handle for a chipping hammer should

Fig. 92.

not exceed 15 inches in length. Soft-wood wedges driven tightly home are better than iron or hard-wood wedges, to wedge the hammer to the shaft.

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FILING.

Large files should be fitted to their handles by making the tine of the file a low red heat, and forcing it into the handle so that it will burn its way into the handle, and thus prevent the handle from splitting, as it would do if the file tine were driven in; the file and handle should be turned in the hands occasionally to guide the eye in detecting whether the file is entering in a line with the length of the handle. Care should be taken to wrap a piece of waste around the end of the file, and to keep it wetted with water so as to avoid softening the teeth of the file while heating the tine. For small files it is sufficient to bore a small hole in the handle and force the tine in by hand. A file should be held so that the butt end of the file handle presses against the centre of the palm of the hand, the forefinger being beneath the body of the file handle.

In selecting a file, choose one that is thickest in the centre of its length, and of an evenly curved sweep from end to end, so as not to make the surface of the work round by filing away the edges. Files that have warped in the hardening may be used on very narrow surfaces, or on round or oval work; or, if they are smooth files, they may be used on lathe work. Keyways or slots, especially, require an evenly rounded file; and if the keyway is long and the file parallel or uneven upon its surface, the end of the file only should be used to ease away the centre of the keyway or the high spots. It is also highly advantageous to rub chalk on the teeth of the file, so that, after a little using, the eye can detect the part of the file which is highest, and govern its use accordingly.

Half-round files should be rounded lengthwise of the half-round side of the file, because it is difficult to file out a sweep evenly, even with a well-shaped file, and it is impossible to do so with a file whose half-round surface is hollow in the direction of its length.

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These files must be used with a side sweep, caused by gradually bending the wrist at every stroke of the file, so that the file marks are not at a right angle to the curve, the sweep of the file being varied occasionally from right to left or from left to right, so that the file marks cross one another, otherwise there will be high ridges or waves in the curve.

Work requiring to be very finely finished with the file should be got up as follows: after the work has been filed up with the bastard file the second cut file should be used, and the smooth file may then be brought into requisition—first, to finely cross-file and then to draw-file. In draw-filing, the motion of the file to produce a very fine surface should be made so that the file marks cross one another, which will prevent the file from cutting scratches. The file should also be kept tolerably clean with the file card, or if filings become locked so fast in the teeth of the file that the file card will not remove them, we may take a piece of tin or a piece of brass or copper, say $\frac{3}{8}$ inch wide, $\frac{1}{32}$ inch thick and about two inches long, and thin the edge at one end by hammering it out. This thin edge we apply to the file, moving it under a pressure across the file lengthways of the teeth, and it will become serrated and fit into the teeth, and remove the filings much cleaner than will a file card. The dead smooth file may be used in the same way after the ordinary smooth file.

To produce the very finest of work we must use the French files, which are smoother, finer and more even in the cut than any other; they are also exceedingly true in their curves and sweep, being superior to any others.

In draw-filing, be careful to note the higher parts of the file and use them only for flat surfaces, also to clean the filings out occasionally to prevent scratches in the work, and to rub chalk upon the file, which will prevent the filings from getting locked in the teeth; then, after every few strokes of the file, brush the hand over it to loosen the

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chalk and filings, and strike it lightly against the screw-box or other soft part of the vise, which is more expeditious than and equally as effective as using the file card every time; when, however, the file requires chalking again, which will easily become apparent, the file card may be advantageously applied before applying the chalk.

Rough or bastard files are used to take off metal in quantity; but if the surface of the work is unusually hard, a second cut file will better answer the purpose. Remember it is less the number of strokes than the pressure placed on the file that takes off the most metal; therefore, stand well off from the vise and put the whole weight of the body on the file. For finishing work very finely, cross-file it with a smooth file and then draw-file it with the same; then cross-file it with a dead smooth file, and draw-file it with the same, using very short strokes of the file and applying chalk to it.

A worn, dead smooth file will finish finer than a new one, and better results will be obtained by finishing the work crosswise of the grain than in a line with it, because any inequality in the texture of the metal will usually run with the grain, and the file teeth will cut the softer parts more readily when following in their length than when merely crossing them. In draw-filing, which should never be done until the work has been cross smooth filed, take short strokes; no matter how long the work may be, long strokes are useless save to make scratches.

EMERY PAPER.

In applying the emery paper for very fine work, use at first No. 1 paper both along and across the work, and repeat the process with No. 0, No. 00, No. 000, or No. 0000, according to the fineness of the polish required, bearing in mind that, the more the emery cloth or paper has been used, the finer is the polish it will give, the reason being that it becomes coated with a glazed surface, composed of parti-

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cles of the metal it has been rubbing; and all metals polish finer and brighter with such a surface than with any other. If the above grades of emery cloth or paper cannot be readily obtained, take the finest grade at hand, and wear it down by using it on a rod or piece of metal in a lathe at a high speed, wiping the rod once during the latter part of the operation with a piece of rag or waste slightly oiled, which will cause the oil to pass to the emery paper, and the latter to retain the particles of metal upon its surface. If this method of polishing be carefully executed, the work may be kept very true and even, and possess a finer finish and polish than by applying oil-stone or by any other known method.

Before commencing any piece of work, measure it all over; and if it has a rectangular part, apply the square to it so as to be assured, before any work has been done to it, that it will clean up to the required dimensions.

TOOLS FOR SCRAPING SURFACES.

Surfaces requiring to be very true may be got up with the scraper, the best form of which is that shown in the Fig. 93, the point *a* being the cutting edge. It is less

Fig. 93.

liable to jar and more readily sharpened than any other. For use on wrought-iron, the cutting edge should be kept moistened, or it will tear the metal instead of cutting it cleanly. All surfaces intended to be scraped should first be filed as true as possible with a smooth file, care being exercised to use a file that is evenly curved in its length and slightly rounding in its breadth. After the surface has been scraped once or twice, a well-worn, dead smooth file may be passed over it, which will rub down the high spots

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of the scraper marks and greatly assist the operation of scraping. Scraping should be executed in small squares, the marks of one square being at a right angle to the marks of the next; then, after the surface plate has been applied, repeat the operation of scraping in squares, but let the marks cross those of the previous scraping. The face of the surface must be wiped off very clean before the surface plate is applied, or the surfaces of both the plate and the work will become scratched. The face of the plate may be moistened by the application of a barely perceptible coat of Venetian red, mixed with lubricating oil, rubbed on by the palm of the hand, to operate as marking to denote the high spots. In applying the surface plate, move it both ways on the work, and reverse it endwise occasionally. If the work is light, it may be taken from the vise and laid upon the plate; but much pressure need not be placed upon the work, or it will spring to suit the surface of the plate, and thus appear to be true when it is not so. Small surfaces should be rubbed on the outer parts of the surface of the plate, by which means the wear on the surface plate will be kept more equal.

VISE CLAMPS.

To prevent the jaws of a vise from damaging finished work, we require a pair, each, of lead and copper clamps. Two pieces of sheet copper $\frac{1}{16}$ inch thick, the width of the vise jaws one way and about six inches the other, will answer to make the copper clamps. The first operation is to soften them by heating them to a low red heat and dipping them in cold water or brine. We then take one of the pieces of copper and grip it in the vise, so that it just covers but does not project below the gripping faces of the vise jaws, and bend the upper part over to fit the outer face of one vise jaw, making it fit the latter neatly all over and hammering it so as to bring the edge nearly sharp. We then take it from the vise and soften it again, and replacing

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it in the vise, hammer it on the upper surface till the edge is sharply defined. We then operate upon the other piece of copper in like manner, thus producing a pair of clamps that, having sharply defined and not rounded, gripping edges, will hold a thin piece of work above the upper face of the clamps without springing the work out of the vice. The object of having the upper surface of the copper so long is so that it will bend far over the upper surface of the vise jaw, and will not be liable to fall off when the vise jaws are opened.

Since copper clamps become hardened through use, it is necessary, when they become glazed, to soften them.

Lead clamps are usually made as wide as the vise jaws, the part covering the gripping faces of the vise jaws being of the same depth as those faces and about $\frac{3}{4}$ inch thick, the upper face of each clamp which laps over the upper jaws of the vise well covering the latter and being about $\frac{3}{8}$ inch thick. Both lead and copper clamps are apt to get filings and grit embedded in their surfaces; hence on delicate work it is well to either place a piece of rag or cloth over them, or else to use a pair of leather clamps, say $\frac{1}{8}$ inch thick, the leather being cut through about half way to cause it to bend over the vise jaws and not fall off when the vise jaws are opened.

Work which presents a small gripping surface to the vise jaws, such for instance as round bolts or spindles, can be held more firmly by lead than by copper clamps, because the work will sink into the lead when the vise is tightened.

VISE WORK—PENING.

The operation termed pening is stretching the skin on one side of work to alter its shape, the principle of which is that, by striking metal with a hammer, the face of the metal struck stretches, and tends to force the work into a circular form, of which the part receiving the effect of the hammer is the outside circle or diameter.

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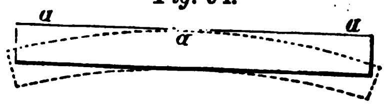
Fig. 94 represents a piece of flat iron, which would, if it

Fig. 94.



were well hammered on the face, *a*, *a*, *a*, with the pene of a hammer, alter its form to that denoted by the dotted lines.

Fig. 95 represents a brass which, if struck with a hammer (along its bore at *a*) or other piece of metal for driving it in while fitting, would gradually assume the form denoted by the dotted lines. Fig. 96 represents a rod connected at the end *a* with a double eye and pin, and requiring to descend true so as to fit into the double eye *b*, at the other end; if, therefore, it is pened perpendicularly on the face *c* of the rod, the stretched

Fig. 95.

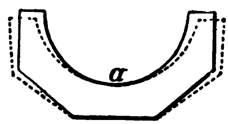
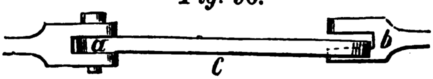


Fig. 96.



skin will throw the end around so that it will come fair with the eye *b*. Connecting rod straps which are a little too wide for the rod ends may be in like manner closed so as to fit by pening the outside of the crown end, or, if too narrow, may be opened by pening the inside of the crown end; but in either case the ends of the strap alter most in consequence of their lengths, and the strap will require refitting between its jaws.

Piston rings may be made of a larger diameter by pening the ring all round on the inside, and there are many other uses to which pening may be used to advantage, such as setting frames, refitting old work, taking the twist

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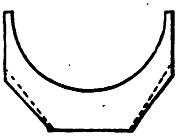
out of work, etc.; but it must be borne in mind that if, after a piece of metal has been pened, a cut is taken off it, it will return to its original shape, as the effects of the pening do not extend more than $\frac{1}{64}$ of an inch in depth. When, therefore, a brass or other work requiring to be bored is driven in and out by a piece of metal or a hammer, it stretches the skin; and when the brass is bored, the stretched skin being cut away, it assumes its original shape and hence becomes slack or loose in the strap or block. A light hammer having a round pene should be used; and light blows should be employed for pening, as they are the most effective.

FITTING BRASSES TO THEIR BOXES.

The pattern for a brass which is hexagonal upon the bottom or bedding part should not be made of exactly the same shape as the hexagonal part of the box upon which it beds, because the brass, in casting, shrinks in the direction of the diameter of the bore to such an extent as seriously to alter the angles of the bottom of the brass as compared with the angles on the bottom of the pattern. To compensate for this change of form, the angles on the sides of the pattern should be made more obtuse than those on the sides of the box, as described in Fig. 97, the dotted lines being the angle of the box. The shrinkage referred to is not merely that due to the contraction of the metal in cooling, but is an alteration of form which takes place in all castings of more or less segmental circular form, especially in the case of light castings. In castings of 4 inches or less diameter, the rapping (given by the moulder to the pattern to loosen it in the sand, so as to be able to extract the pattern without damaging the mould) is about equal to this alteration of form; but in larger castings an allowance must be made for it.

Fig. 97.



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In fitting a brass to its box, first fit the sides of the brass to the box, keeping them at an equal angle to the joint or top face of the brass, so as to let the brass down evenly and not with one side or one bevel lower than the other. To find if the brass is level, use inside calipers as a gauge, applied from the top face of the brass to the top face of the box. When the brass is let down so that it approaches the bottom of the box, rub upon the bed of the box a coating of marking; and then upon the end of each bevel, and upon the bottom and near each corner (of the bevels and bottom), place some small pellets of red lead, mixed stiffly; then when the brass is driven home upon its bed and again taken out, the pellets of red lead will adhere to the box because of the marking, and (by their respective thicknesses) denote how nearly the angles or bevels of the brass fit to the box; because where the brass touches the bed of the box, the pellets will be mashed; but if the pellets are intact, it demonstrates that there is space between the box and the brass. It is obvious that the brass requires chipping in those places where the pellets are crushed, and in proportion to the thickness of the pellets that are the least crushed. The pellets should be removed and replaced each time before driving the brass home, and removed when they appear of even thicknesses, the fitting being completed with marking only. All brasses must be fitted to their boxes more tightly than they are intended to be when finished, because they go in from the process of boring and are consequently an easier fit after than before being bored.

FITTING LINK MOTIONS.

The planing and boring of the link of the die, and of the eccentric rod double eyes being completed, the faces of the links may be filed up to a surface plate. The slot of the link should then be filed out to a gauge of sheet-iron of the proper sweep, the sides of the slot being kept square at all

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parts with the face of the link: each end of the slot at the termination of the stroke of the die should be eased off a little, so that, when the link and the die are hardened, the latter will not bind hard in the ends of the former, as would otherwise inevitably be the case. The die may then be fitted, to a rather tight fit, to the slot of the link, putting a very light coat of marking upon either or both of them, which will serve as a lubricant to prevent them from cutting, and will show the high spots upon both the link and the die, which spots must be eased off until the die fits to a working fit, providing the link and die are not intended to be hardened. If, however, they are to be hardened, the die must be made of a somewhat easier fit to allow for the expansion of the metal which takes place in hardening. To fit the double eyes (that is, the eccentric rod ends) upon the link (or quadrant), a bolt and washer should be provided, the pin being a fit to the hole in the eye and to the hole in the washer, the head of the pin and the washer being the finished diameter of the outside of the eye. The end of the pin is passed through one side of the eye, then through the washer, and then through the other side of the eye.

The underneath faces of the pin and washer will, if revolved by hand, mark the two faces (against which they bear) true with the hole of the double eye; and when those faces are finished, the pin may be turned end for end, and the other two faces trued in the same manner. The object of making the head of the pin and the washer of the same diameter as the double eye is that they may be used as gauges to which to file up the outside of the double eye, for which purpose they should be hardened so that the file will not cut them. The double eyes being filed to fit the link, the washer (having been used, as above described, as a gauge to keep the faces true to the hole) must then be clamped to the link, care being taken to make the hole of the link as true as possible with the hole of the double eye,

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and to slacken the bolt of the clamp if the double eye requires moving to come fair with the hole in the link. If the clamp were not slacked, striking the double eye to move it would probably spring one jaw out of true with the other. A hand reamer may be passed through the double eye, taking out a light cut, and thus making the holes through the link and double eye parallel and quite true with each other.

If, after the link has been hardened, the die is too tight a fit, place oil and fine emery in the slot, put the die in its place and (with a piece of wood through the hole of the die) force it back and forth from end to end of the slot, or in such parts only as it may be too tight; this will grind out the tight places. If there is no fine emery at hand, crush some coarse emery, using a hammer and a block of iron. If the link is tight at the extreme ends, as is sometimes the case, a piece of flat copper shaped and used as a file may be used with grain emery and oil to grind out such ends. If, however, the link has altered so much as to make the grinding a long and tedious operation, it may be opened by placing a bolt and nut in such a position in the slot that the head of the bolt will rest against one side and the end face of the nut against the other side of the slot; the head of the bolt should then be held stationary with a wrench or spanner, and the nut, being unscrewed, will force open the link. Another method is to take two keys, such as connecting-rod keys, both having an equal amount of taper on them, and place them in the slot of the link with their edges bearing against each, and with the heads of the keys on opposite sides of the link. The operation is to place a hammer against the head of one key, to prevent it from driving out of the link, and to drive in the other key. The advantage of this method over the screw and nut is this: The link will spring considerably before it will alter its form, so that, when applying the bolt and nut, it is difficult, in the second operation (pro-

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viding the first has not effected the desired opening of the link), to find exactly how much to unscrew the nut. In using the keys, however, lines may be drawn across the keys to denote exactly how far they were driven in during the first operation, which lines will guide the judgment as to how far to drive them in the second operation. If a link opens, that is, if the slot becomes wider during the process of hardening, it may be closed by clamping, or even by a strong vise.

FITTING CYLINDERS.

A casual cylinder or pair of cylinders (there being no templates for marking the holes, etc.) should be fitted up as follows: If that part of the cylinder cover which fits into the cylinder has a portion cut away to give room for the steam to enter (as is usually the case), mark a line across the inside flange of the cover, parallel to the part cut away, and then scribe each end of the line across the edge of the flange. Then mark a similar line across the cylinder end, parallel to the steam port where it enters the cylinder, and scribe each end of this line across the cylinder flange, so that, when the cylinder cover is placed into the cylinder and the lines on the flanges of the cylinder and the cover are placed parallel to each other, the piece cut away on the cover will stand exactly opposite to the steam port, as it is intended to do. The cover may then be clamped to the cylinder, and holes of the requisite size for the tap (the tapping holes, as they are commonly called) may be drilled through the cover and the requisite depth into the cylinder at the same time. Concerning the correct size of a tapping hole in cast-iron, as compared to the tap, there is much difference of opinion and practice. On the one hand, it is claimed that the size of the tapping hole should be such as to permit of a full thread when it is tapped; on the other hand, it is claimed that two-thirds or even one-half of a full thread is all that is necessary in holes in cast-iron, because such a thread is, it is claimed,

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equally as strong as a full one, and much easier to tap. In cases where it is not necessary for the thread to be steam-tight and where the length of the thread is greater by at least $\frac{1}{8}$ inch than the diameter of the bolt or stud, three-quarters of a full thread is all that is necessary, and can be tapped with much less labor than would be the case if the hole was small enough to admit of a full thread, partly because of the diminished duty performed by the tap, and partly because the oil (which should always be freely supplied to a tap) obtains so much more free access to the cutting edges of the tap. If a long tap is employed to cut a three-quarter full thread, it may be wound continuously down the hole, without requiring to be turned backwards at every revolution or so of the tap, to free it from the tap cuttings or shavings, as would be necessary in case a full thread was being cut. The saving of time in consequence of this advantage is equal to at least 50 per cent. in favor of the three quarter full thread.

The cylinder covers must, after being drilled, as above, be taken from the cylinder, and the clearing drill put through the holes already drilled so that they will admit the bolts or studs, the clearing holes being made $\frac{1}{16}$ inch larger than the diameter of the bolts or studs. The steam-chests may be either clamped to the cylinder, and tapping holes drilled through it and the cylinder (the same as done in the case of the covers) or it may have its clearing holes drilled in it while so clamped, care being taken to let the point of the drill enter deep enough to pass completely through the steam-chest, and into the cylinder deep enough to cut or drill a countersink nearly or quite equal to the diameter of the drill. If, however, the steam-chest is already drilled, it may be set upon the cylinder, and the holes marked on the cylinder face by a scriber, or by the end of a piece of wood or of a bolt, which end may be made either conical or flat for the purpose, marking being placed upon it; so that, by putting it through the hole of

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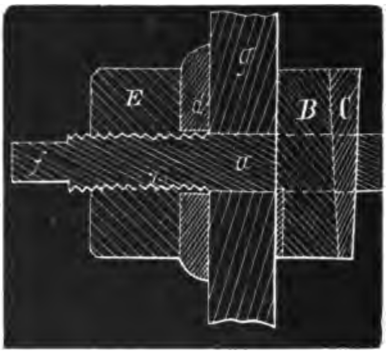
the chest, permitting it to rest upon the cylinder face (which may be chalked so as to show the marks plainly), and then revolving it with the hand, it will mark the cylinder face. This plan is generally resorted to when the holes in the chest are too deep to permit of being scribed. To true the back face, round a hole against which face the bolt head or the face of the nut may bed (in cases where such facing cannot be done by a pin countersink or a cutter used in a machine), the appliance shown in Fig. 98 may be employed, *a* being a pin provided with a slot at one end to

Fig. 98.



admit the cutter B, which is held fast by the key C, and is also provided with a square end *f*, by which it may be turned or revolved by means of a wrench, and with a thread to receive the nut E, *d* being a washer; so that, by screwing up the nut E, the cutting edges of the cutter are forced against the cylinder *g*, and will, when revolved, cut the face against which they are forced, true with the hole in the cylinder through which the pin *a* is passed.

To fit the cylinder cover joint, put marking on the joint face of the cover; put the cover into its place on the cylinder face; then, in order to discover how much the faces are out of true, strike the outside of the cover on one side of its

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diameter, and then the other, alternately, with the fist; and if the faces at any point are open, they will strike each other with a blow the sound of which will clearly indicate to what extent they are out of true; if much, the cover may be removed and the high parts rough-filed to any extent the judgment may indicate; if, however, when the cover is struck, the faces give no sound of striking, smooth filing will answer. When the faces mark nearly all over, the high spots may be eased with the scraper until the surfaces are sufficiently close that a light coating of marking will mark them all over, when they may be ground together as follows: Place on the cylinder face grain emery and oil, and then put the cover on. Fasten to the cover a lever, and then place sufficient weight upon the cover to leave it capable of being conveniently moved by means of the lever (which should project on both sides of the cover). The cover must not be revolved all in one direction, or the emery will cut grooves in the face, but must be moved back and forth while it is being revolved. When the grinding has proceeded until the cover moves smoothly upon the cylinder face, indicating that the emery has worn down and worked out (as it will do) from between the faces, the cover may be removed; and if the grinding appears equal and of one shade of color all over the faces, the emery may be wiped off them, and the cover replaced and revolved back and forth as before, which will cause the faces to polish each other, removing all traces of the emery, and showing plainly the slightest defect in the surfaces. If, however, the first grinding is not sufficient (as is generally the case), oil and emery must be again supplied, and the grinding continued as in the first instance. The cover of an 18 inch cylinder, even if it is much out, may be made of a steam-tight fit by this process in about half an hour.

It is obvious that, in the case of a large cylinder cover, such as are used for marine purposes, the hand will not strike a sufficient blow to indicate how much the faces, before

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fitting, are out of true, and a block of wood and a hammer must be employed instead.

The next operation is to cut out the cylinder ports to their requisite dimensions.

In facing up the valve faces, the surface plate may, in like manner, be struck on its opposite corners, or a pressure may be placed on them by the hands to ascertain if the surface plate will rock, and to what extent. If it rocks at all, a rough file should be employed to file away the high parts of the face; if it does not rock, a smooth file should be employed to take out the tool marks, the filing being continued until a light coat of marking on the surface plate will mark the cylinder face all over, when the scraper may be applied to finish it. The slide valve itself may then be surfaced and scraped to the surface plate, and then placed upon the cylinder face, and the valve and cylinder face scraped together.

The joint of the steam-chest may be made by filing the planed surfaces to a straight edge, and placing between the chest and its seat on the one hand, and the cover and the chest on the other hand, a lining of very thin softened sheet copper, which plan is generally adopted on cylinders for locomotives.

In cases where a number of cylinders of similar sizes are made, the whole of the marking off, and much other work, may be saved by the employment of gauges, etc.

For drilling the cylinder covers and the tapping holes in the cylinder, the following system is probably the most advantageous: The flanges of the cylinder covers are turned all of one diameter, and a ring is made, the inside diameter of which is, say, an inch smaller than the bore of the cylinder; and its outside diameter is, say, an inch larger than the diameter of the cover. On the outside of the ring is a projecting flange which fits on the cover, and which is provided with holes, the positions of which correspond with the required positions of the holes

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in the cover and cylinder; the diameter of these holes (in the ring, or template, as it is termed) is at least one quarter inch larger than the clearing holes in the cylinder are required to be. Into the holes of the template are fitted two bushes, one having in its centre a hole of the size necessary for the tapping drill, the other a hole the size of the clearing drill; both these bushes are provided with a handle by which to lift them in and out of the template, and both are hardened to prevent the drill from cutting them, or the borings of the drill from gradually wearing their holes larger. The operation is to place the cover on the cylinder and the template upon the cover, and to clamp them together, taking care that both cover and template are in their proper positions, the latter having a flat place or deep line across a segment of its circumference, which is placed in line with the part cut away on the inside of the cover to give free ingress to the steam, and the cover being placed in the cylinder, so that the part so cut away will be opposite to the port in the cylinder, by which means the holes in the covers will all stand in the same relative position to any definite part of the cylinder, as, say, to the top or bottom, or to the steam-port, which is sometimes of great importance (so as to enable the wrench to be applied to some particular nut, and prevent the latter from coming into contact with a projecting part of the frame or other obstacle). The bush, having a hole in it of the size of the clearance hole, is the one first used, the drill (the clearance size) is passed through the bush, which guides it while it drills through the cover, and the point cuts a countersink in the cylinder face. The clearing holes are drilled all round the cover, and the bush, having the tapping size hole in it, is then brought into requisition, the tapping drill being placed in the drilling machine, and the tapping holes drilled in the cylinder flange, the bush serving as a guide to the drill, thus causing the holes in the cover and those in the cylinder to be quite true with each other. A

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similar template and bush is provided for drilling the holes in the steam-chest face on the cylinder, and in the steam-chest itself. While, however, the cylinder is in position to have the holes for the steam-chest studs drilled, the cylinder ports may be cut as follows, which method was introduced in 1867, with marked success, by Mr. John Nichols, who was then manager of the Grant Locomotive Works at Paterson, N. J.: The holes in the steam-chest face of the cylinder being drilled and tapped, a false face or plate is bolted thereon, which plate is provided with false ports or slots, about three-eighths of an inch wider and three-fourths of an inch longer than the finished width and length of the steam-ports in the cylinder (which excess in width and length is to allow for the thickness of the die). Into these false ports or slots is fitted a die, to slide (a good fit) from end to end of the slots. Through this die is a hole the diameter of which is that of the required finished width of the steam-ports of the cylinder. Into the hole of the die is fitted a reamer, with cutting edges on its end face and running about an inch up its sides, terminating in the plain round parallel body of the reamer, whose length is rather more than the depth of the die. The operation is to place the reamer in the drilling machine, taking care that it runs true, place the die in one end of the port, and then wind the reamer down through the die so that it will cut its way through the port of the cylinder at one end; the spindle driving the drill is then wound along. The reamer thus carries the die with it, the slot in the false face acting as a guide to the die.

In the case of the exhaust port, only one side is cut out at a time. It is obvious that, in order to perform the above operation, the drilling machine must either have a sliding head or a sliding table, the sliding head being preferable.

The end of the slot at which the die must be placed when the reamer is wound down through the die and cylinder port, that is to say, the end of the port at which the operation of

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cutting it must be commenced, depends solely on which side of the port in the cylinder requires most metal to be cut off, since the reamer or cutter, as it may be more properly termed, must cut underneath the heaviest cut, so that the heaviest cut will be forcing the reamer back. The reason for the necessity of observing these conditions, as to the depth of cut and direction of cutter travel, is that the pressure of the cut upon the reamer is in a direction to force the reamer forward and into its cut on one side, and backward and away from its cut on the other side, the side having the most cut exerting the most pressure. If, therefore, the cutter is fed in such a direction that this pressure is the one tending to force the cutter forward, the cutter will spring forward a trifle, the teeth of the cutter taking in consequence a deep cut, and, springing more as the cut deepens, terminate in a pressure which breaks the teeth out of the cutter. If, however, the side exerting the most pressure upon the reamer is always made the one forcing the cutter back, by reason of the direction in which the cutter is travelled to its cut, the reamer in springing away from the undue pressure will also spring away from its cut, and will not, therefore, rip in or break, as in the former case.

In cutting out the exhaust port, only one side, in consequence of its extreme width, may be cut at one operation; hence there are two of the slots provided in the false plate or template for the exhaust port. The cutter must, in this case, perform its cut so that the pressure of the cut is in a direction to force the cutter backwards from its cut. The time required to cut out the ports of an ordinary locomotive cylinder, by the above appliance, is thirty minutes, the operation making them as true, parallel, and square as can possibly be desired.

In order to tap the holes in the cylinder heads and steam-chest seat on the cylinder true, without requiring the workman to apply the square, a long tap and a guide

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is employed for holding the guide to the cylinder face. If the end cylinder faces have a projecting ring on them (so as to leave a small surface to make the joint), the guide may be cut away on its bottom face to fit the projection, so that if the guide is held against the projection, while the guide is bolted fast, the hole in the guide through which the tap passes will stand true (both ways) of itself, to the hole to be tapped in the cylinder. In the case, however, of there being no projection of the kind mentioned, as, for instance, when tapping the holes in the seat for the steam-chest, the guide will require adjusting sideways, by the eye. The distance, however, of the holes in the guide being the same from centre to centre as the distance from centre to centre of the holes to be tapped, insures, without any setting, that the holes tapped are true with each other one way.

The saving of time and labor effected by means of the employment of this system and its appliances is much greater than might be supposed at first sight; it may, however, be appreciated when it is stated that, under it, three pairs of locomotive cylinders have been fitted up by one skilled workman and one assistant in seven and a half days, the work done to each pair being the holes, amounting to 200, drilled, and those for the cylinder covers, cylinder cocks, steam-chests, steam-pipes, and exhaust-pipes, tapped; the steam and exhaust ports cut out, and the faces and those of the slide valves scraped up, the cylinder end and cover faces filed, scraped, and ground up steamtight, the steam-chest seat faces filed up true to a straight edge, the seat for the steam and exhaust ports faced out with the cutter, all necessary bolts and studs put in, the cylinders bolted together, their bores being set true with each other, and the whole turned out so that the cylinders were complete and ready to bolt to the engine frames.

For screwing the studs into a cylinder the following tool should be used: a piece of iron, say four inches long,

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should have one end cut square for a wrench to fit, and in the other end a hole, tapped clear down to its bottom and fitting the thread of the stud loosely; the stud will then bottom in it when being screwed in, while, when the stud is home in the cylinder, the tool will leave it easily without unscrewing it again.

SCRAPED SURFACES.

There are many who believe that surfaces properly planed are sufficiently true for all ordinary practical purposes; but if those persons were to apply a surface plate to a well-planed surface a foot square, or to a common connecting rod, key and gib, as they usually leave the planer, they would be effectually cured of the fallacy of their opinion upon this matter.

It is impossible to hold a piece of work sufficiently firm that it can be cut by a machine tool without springing it; and though in stout work having a fair bedding beneath the clamping bolts, and in work in which the pressure referred to is sustained in a direction to directly compress the metal of the work, the amount of this spring may be almost imperceptible, still, in light and in a great deal of other work, the amount of spring due to the pressure of holding the work is sufficiently great to throw it out of true. Another of the reasons for the necessity of using surface plates is, that all work alters its form from having its surface skin removed, as will be hereafter explained. All working flat surfaces should be surfaced to a surface plate, whether they are intended to be finished with a file or a scraper. Scrapers are not intended for use as tools to take off a quantity of metal, but for the purpose of making the work very true, being used by itself or in conjunction with a file to ease away the high spots; not because it is impossible with a file of even sweep and flat cross surface to file true, but because it is a quicker and easier method of obtaining a flat surface, and one that is absolutely indis-

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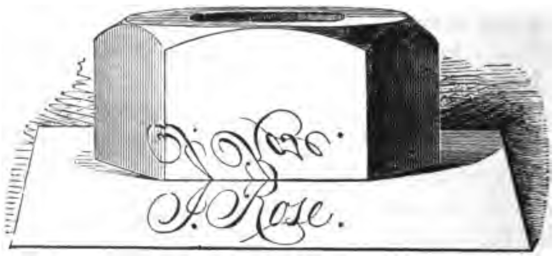
pensable to fine work if the file has warped to a sensible degree in the hardening. If, after a piece of work has been planed and the surface plate has been applied, it is found that the surface is somewhat out of true, as is generally the case, it is better to file the work until the surface is true, which process will be quicker than scraping from the commencement.

It is useless to apply a scraper promiscuously over a surface for the purpose of making it appear smooth; for a surface can be got up, so far as smoothness is concerned, far better with a file and emery paper than it can be with a scraper. Fig. A represents a surface finished by a file and emery paper, the surface being so fine that even common paper will scratch it.

Fig. A.



The proper method of procedure in scraping a flat surface is to first go all over it, leaving the scraper marks as shown in Fig. B.

The second time of going over the surface should leave the marks as shown in Fig. C; while the surface will appear after the third scraping as in Fig. D.

After each scraping we apply the surface plate and rub it well over the work to mark it, giving the surface of the plate a barely perceptible coat of marking, and distributing the same evenly all over with the palm of the hand, so as to detect any grit that may chance to have got into the

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marking. A piece of *old* rag should be used for wiping the surfaces clean (which is better than either new rag or

Fig. B.

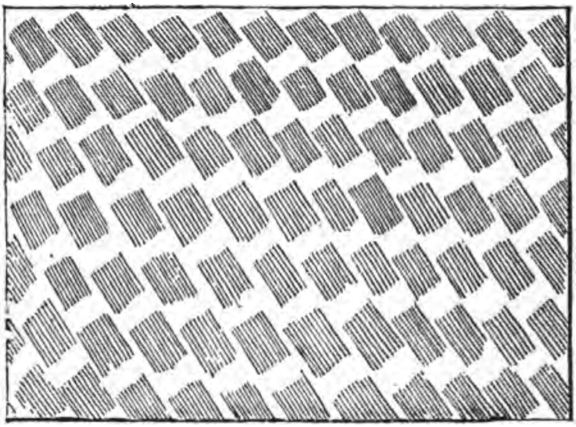
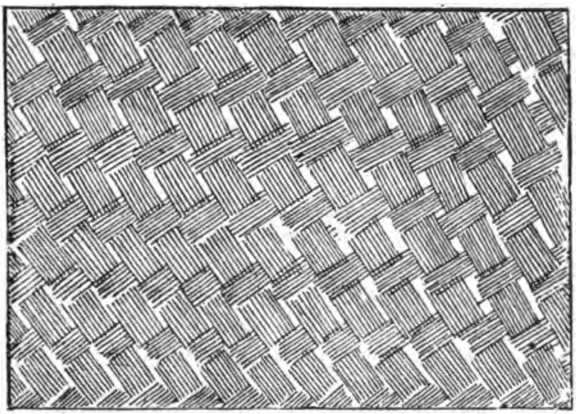


Fig. C.



waste) and great care should be taken that the surfaces have no dust or grit upon them, or it will scratch the sur-

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faces. The surface plate is made to mark the work by being rubbed back and forth upon it, or, if the work is small, it may be taken from the vise and rubbed upon the face of the surface plate. In either case, the high spots upon the face of the work will become very dark, or, if the amount of marking applied was barely sufficient to dull the surface of the plate, the marks will be almost black and will, by continuous rubbing on the plate, become bright.

Here we may observe that small work applied to the

Fig. D.

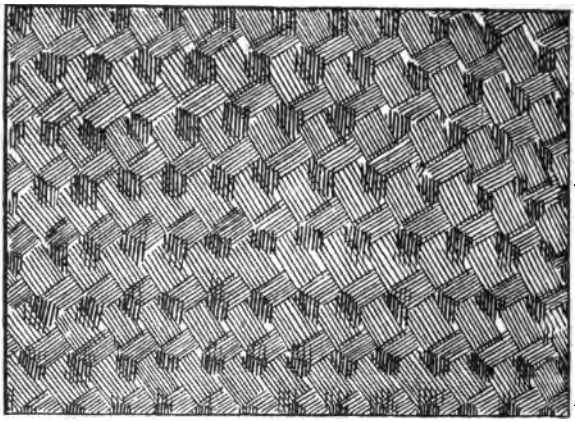

plate should be rubbed at the corners and toward the outer edges of the plate so as to keep the wear of the latter as even as possible, since the middle of the surface of the plate generally suffers the most from use, becoming in time hollow.

The harder the plate bears upon the work the darker the spots, where it touches, will appear; so that the darker the spots the heavier the scraping should be performed. It will be noted that the scraper marks are much smaller and finer at and during the last scrapings, and it may be

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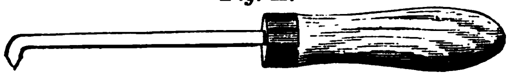
here remarked that the scrapings are taken very light and in a direction lengthwise of the surface plate marks during the finishing process.

The best form of scraper is that shown in Fig. E, which should be ground down so that the cutting edge does not

Fig. E.



stand more than a quarter of an inch from the body of the tool during the finishing process; for the edge will not cut so smoothly if the cutting end and edge is bent far out. After the scraper is ground, it should be carefully oil-stoned to a smooth edge. For use upon brass, wrought-iron and steel, the cutting edge should be kept moistened with water.

TO MAKE A SURFACE PLATE.

To obtain a true surface plate we must *first* get up three plates, which we will term numbers 1, 2 and 3.

We take No. 1, and placing a true straight edge across it we take one end of the straight edge, between the finger and thumb, and taking care not to place any vertical pressure upon it, we move it sideways back and forth about an inch, to see where on the plate the fulcrum of its movement takes place. If the centre of its movement is at the centre of the plate, then the surface of the plate is rounding—that is, highest in the middle. If the straight edge moves on the plate, first, the most at one end, and then the most at the other end, it demonstrates that the straight edge takes its fulcrum of movement towards the edges of the plate, and hence that the latter is hollow. If, however, the straight edge moves with a shuffling movement, it denotes that the plate is neither rounding nor hollow. The surface, however, may nevertheless be atwist and the straight edge will not detect it, unless two are used—being placed parallel to each other, one at the opposite side of the plate to the other—when, if the straight edges

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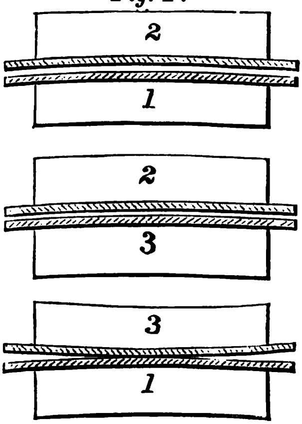
are sufficiently long, the eye, directed across the upper edges of the straight edges, looking at them sideways, will readily detect any twist. Having levelled Nos. 1 and 2 as near as possible by the straight edge, we place marking on one of them and then rub their surfaces well together, to mark them, and then proceed to scrape them until they fit together. We should, however, when putting their faces together for the first time, strike the back of the top plate a sharp blow at each corner with the closed hand, and if the surfaces are atwist at all, a blow distinctly heard will be given by the top plate to the bottom one; the degree of loudness of the blow will also denote how much the surfaces are out of true. It may be thought that the surfaces, being planed, cannot well be atwist. Such, however, is not the case, nor is the twist due to the planing but to the alteration of form which takes place in the work, by reason of the tension of the skin upon the face having been removed. This alteration of form may be reduced to a minimum by slacking back the bolts, plates or jaws, holding the work in the planer, previous to taking the last cut in the planer, since the last cut being a light one, not much pressure is required to hold the work.

Fig. F.



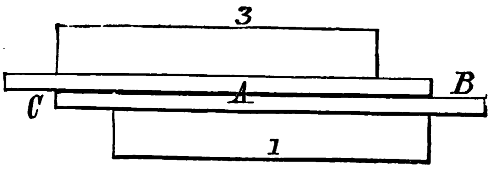
Having scraped Nos. 1 and 2 together, we introduce No. 3 and scrape it to fit No. 2, not scraping the latter at all. We next try Nos. 1 and 3 together, and if they show each other to be rounding, it is proof that No. 1 is rounding to one-half the amount of difference between it and No. 3 as shown in Fig. F.; from which it will be perceived that the two nearest together faces of 1

and 2 may fit together, one being rounded and the other hollow. No. 2 may then be taken as a gauge whereby to fit No. 3. But if we then take Nos. 1 and 3, and try them together, they will disagree to twice the amount that each of them separately is out—that is to say, twice the amount that No. 1 varied from being a true flat surface.

We next scrape Nos. 1 and 3 together, taking off, as nearly as our judgment dictates, an equal amount off each with the scraper, and this being complete, we scrape No. 2 to No. 1, and then No. 3 to No. 2, finally bringing back No. 3 to No. 1, as a test, scraping them together, taking an equal amount off each, and when they fit perfectly we fit 2 again to 1, and 3 again to 2, continuing the whole operation until all three plates fit, each the others, perfectly.

Here, however, we may note as follows: the three plates being of the same size, as they should be, and it being necessary to rub their faces together in order to mark where they touch together, the abrasion of one face against the other, and therefore the marks, will not be equal. Thus, in Fig. G, plate 1 being moved forward, that part

Fig. G.



of its surface overlapping and denoted by C, and that part of plate 2 denoted by B, are not in contact with a surface, and are not, therefore, being marked by the movement, whereas the whole of the rest of the surfaces of the two plates *are* in contact, and are therefore marking each other during the whole of the movement, the consequence being that those parts of the surfaces which overlap mark more lightly in proportion to the amount of their bearing than

the rest of the surfaces, and since it is the lightness or heaviness of the marks which determine how much the parts of contact must be eased by the scraper, it becomes evident that a surface plate cannot be made true to the highest practical attainable degree, unless, having finished the three plates, we introduce a *fourth*, whose size shall be sufficiently smaller that it can be rubbed back and forth upon the plate or plates by which it is surfaced without overlapping at all. The feet upon which a surface plate rests should be planed true, and the plate resting upon the bench should rest equally upon all of the feet, otherwise the plate will deflect from its own weight, the amount of the deflection making a practical difference in a large plate.

TO CUT HARD SAW BLADES.

Mark out on the saw blade the article you require to cut from it and centre-punch it lightly all along the lines, going over and over it until the centre-punch marks, which should not be more than $\frac{1}{16}$ inch apart, are nearly through the blade; then take a hard chisel and nick between and along the centre-punch marks. Then reverse the saw blade, and centre-punch from the other side, and the blade will cut to almost any shape without splitting.

Keys should be made a snug fit and parallel on the sides, having taper on the top and bottom only. They should be fitted to bear even all over, or they spring the work out of true. A very light coat of marking should be used in fitting them, and they should be driven in and out lightly.

TO REFIT LEAKY PLUGS TO THEIR COCKS.

When a cock leaks, be it large or small, it should be refitted as follows, which will take less time than it would to ream or bore out the cock or to turn the plug, unless the latter be very much worn indeed, while in either case the plug will last much longer if refitted, as hereinafter directed, because less metal will be taken off it in the refitting.

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After removing the plug from the cock, remove the scale or dirt which will sometimes be found on the larger end, and lightly draw-file, with a smooth file, the plug all over from end to end. If there is a shoulder worn by the cock at the large end of the plug, file the shoulder off even and level. Then carefully clean out the inside of the cock, and apply a very light coat of red marking to the plug, and putting it into the cock press it firmly to its seat, moving it back and forth part of a revolution; then, while it is firmly home to its seat, take hold of the handle end of the plug, and pressing it back and forth at a right angle to its length, note if the front or back end moves in the cock; if it moves at the front or large end, it shows that the plug is binding at the small end, while if it moves at the back or small end, it demonstrates that it binds at the front or large end. In either case, the amount of movement is a guide as to the quantity of metal to be taken off the plug at the requisite end to make it fit the cock along the whole length of its taper bore. The red marking referred to is dry Venetian red and lubricating oil, mixed thickly, a barely perceptible coating being sufficient.

If the plug shows a good deal of movement when tested as above, it will be economical to take it to a lathe, and, being careful to set the taper as required, take a light cut over it. Supposing, however, there is no lathe at hand, or that it is required to do the job by hand, which is, in a majority of cases, the best method, the end of the cock bearing against the plug must be smooth filed, first moving the file round the circumference, and then draw-filing; taking care to take most off at the end of the plug, and less and less as the other end of the plug is approached. The plug should then be tried in the cock again, according to the instructions already given, and the filing and testing process continued until the plug fits perfectly in the cock. In trying the plug to the cock, it will not do to revolve the plug continuously in one direction, for that would cut rings

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in both the cock and the plug, and spoil the job; the proper plan is to move the plug back and forth at the same time that it is being slowly revolved. As soon as the plug fits the cock from end to end, we may test the cock to see if it is oval or out of round, as follows: First give it a very light coat of red marking, just sufficient, in fact, to well dull the surface, and then insert the plug, press it firmly home, and revolve it as above directed; then remove the plug, and where the plug has been bearing against the surface of the cock, the latter will appear bright. If, then, the bore of the cock appears to be much oval, which will be the case if the amount of surface appearing bright is small, and on opposite sides of the diameter of the bore, these bright spots may be removed with the half-round scraper. Having eased off the high spots as much as deemed sufficient, the cock should be carefully cleaned out (for if any metal scrapings remain they will cut grooves in the plug), and the red marking reapplied, after which the plug may be again applied. If the plug has required much scraping, it will pay to take a half-round smooth file that is well rounding lengthwise of its half round side, so that it will only bear upon the particular teeth required to cut, and selecting the highest spot on the file, by looking down its length, apply that spot to the part of the bore of the cock that has been scraped, draw-filing it sufficient to nearly efface the scraper-marks. The process of scraping and draw-filing should be continued until the cock shows that it bears about evenly all over its bore, when both the plug and the cock will be ready for grinding.

Here, however, it may be as well to remark that in the case of large cocks we may save a little time and insure a good fit by pursuing the following course, and for the given reasons. If a barrel bears all around its water-way only for a distance equal to about $\frac{1}{16}$ of the circumference of the bore, and the plug is true, the cock will be tight, the objection being that it has an insufficiency of wearing

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surface. It will, however, in such case wear better as the wearing proceeds. There is perhaps the further objection that so small an amount of wearing surface may cause it to abrade. This, however, has nothing to do with our present purpose, which is to save time in the grinding, insure a good fit, and, at the same time, ample wearing surface. One plug and barrel being fitted as directed, we may take a smooth file and ease very lightly away all parts of the barrel, save and except to within say $\frac{3}{8}$ inch around the water or steam way. The amount taken off must be very small—indeed, just sufficient, in fact, to ease it from bearing hard against the plug, and the result will be that the grinding will bed the barrel all over to the plug, and insure that the metal around the water or steam-way on the barrel shall be a good fit, and hence that the cock be tight. In the case of large cocks, the barrel and the plug should stand vertical during both the filling trials and the grinding process.

The best material to use for the grinding apparatus is the red burnt sand from the core of a brass casting, which should be sifted through fine gauze, and riddled on the work from a box made of say a piece of $1\frac{1}{2}$ pipe 4 inches long, closed at one end, and having fine gauze instead of a lid. Both the barrel and the plug should be wiped clean and free from filings, etc., before the sand is applied; the inside of the barrel should be wetted, and the plug dipped in water, the sand being sifted, a light coat, evenly over the barrel and the plug. The plug must then be inserted in the barrel without being revolved at all till it is home to its seat, when it should be pressed firmly home, and operated back and forth while being slowly revolved. It should also be occasionally taken a little way out from the barrel and immediately pressed back to its seat and revolved as before, which will spread the sand evenly over the surfaces and prevent it from cutting rings in either the barrel or the plug. This process of grinding may be repeated, with fresh

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applications of sand, several times, when the sand may be washed clean from the barrel and the plug, both of them wiped comparatively dry and clean, and the plug be reinserted in the barrel, and revolved, as before, a few revolutions; then take it out, wipe it dry, reinsert and revolve it again, after which an examination of the barrel and plug will disclose how closely they fit together, the parts that bind the hardest being of the deepest color. If, after the test made subsequent to the first grinding operation, the plug does not show to be a good, even fit, it will pay to ease away the high parts with a smooth file, and repeat afterwards the grinding and testing operations.

To finish the grinding, we proceed as follows: give the plug a light coat of sand and water, press it firmly to its seat, and move it back and forth while revolving it, lift it out a little from its seat at about every fourth movement, and when the sand has ground down and worked out, remove the plug, and smear over it evenly with the fingers the ground sand that has accumulated on the ends of the plug and barrel; then replace it in the barrel, and revolve as before until the plug moves smoothly in the barrel, bearing in mind that if at any time the plug, while being revolved in the barrel, makes a jarring or grating sound, it is cutting or abrading from being too dry. Finally, wipe both the barrel and the plug clean and dry, and revolve as before until the surfaces assume a rich brown, smooth and glossy appearance, showing very plainly the exact nature of the fit. Then apply a little tallow, and the job is complete and perfect.

REFITTING WORK BY SHRINKING IT.

For closing long holes, boxes, etc., the water process may be employed, as represented in Fig. H. *a a* is the section of a wrought-iron square box or tube, which is supposed to be made red hot and placed suddenly in the water, B, from its end C to the point D, and held there until the end

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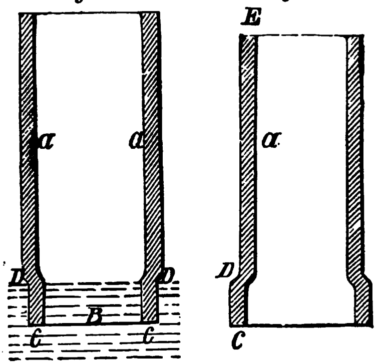
submerged is cold; the result is that the metal in the water, from C to D, contracts or shrinks in diameter, and compresses the hot metal immediately above the water-line,

Fig. H. *Fig.* J.



as the small cone at D denotes. If, then, the box or tube is slowly immersed in the water, this action of compression is carried all the way up from that point, and its form, when cold, will be as described in Fig. J, that part from C to D maintaining its original size, and the remainder being smaller.

It must then be reheated and suddenly immersed from the end E nearly to D, held there until it is cold, and then slowly lowered in the water, as before, which will contract the part from D to C, making the entire length parallel but smaller, both in diameter and bore, than before it was thus operated upon.

Small holes to be reduced in bore by this process should be filled with fire clay, and the faces nearly or wholly covered with the same substance, so that the water will first cool the circumference, and the circumference will, in contracting, force inwards the metal round the hole, which is prevented from cooling so quickly by the clay, and

therefore gives way to the compressing force of the outside and cooler metal.

This principle may be made use of for numerous purposes, as for reducing diameters of the tires of wheels, reducing the size of wrought-iron bands, or for closing in connecting rod straps to refit them to the block end, the mode of operation for which is, in the case of a rod whose strap is held by bolts running through the block and strap, to bolt the strap on the rod to prevent it from warping, to then heat the back of the strap, and (holding the rod in a vertical position) submerge the back of the strap in water to nearly one-half its thickness.

If the bolts are not worn in the holes, or if the strap is one having a gib and key, they may be merely put into their places without placing the strap on the rod. Even a plain piece of iron shrinks by being heated and plunged into water, but only to a slight degree, and the operation cannot be successfully repeated. Eccentric rods, which require to be shortened, say $\frac{1}{64}$ of an inch, may be operated on in this manner, in which case care must be taken to immerse them evenly so as not to warp them.

Much labor and expense may often be saved by employing the principles of expansion and contraction to refit work. For instance, suppose a bolt has worn loose: the bolt may be hardened by the common prussiate of potash process, which will cause it to increase in size, both in length and diameter. The hole may be also hardened in the same way, which will decrease its diameter; and if the decrease is more than necessary, the hole may be ground or "lapped" out by means of a lap. Only about $\frac{1}{64}$ of an inch of shrinkage can be obtained on a hole and bolt by hardening, which, however, is highly advantageous when it is sufficient, because both the hole and the bolt will wear longer for being hardened.

Set screws should be made of steel, the end being cupped and the thread at the end being chamfered off, and that end being hardened.

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To put a fixed feather in a shaft, cut out the seat for the feather and then take a chisel-set, and bulge out the sides of the recess. The feather (which should have the part intended to be set in the shaft slightly dovetailed, the largest part of the dovetail resting on the bottom of the recess) should then be put in its place, and the metal of the shaft should be closed around the feather, a set being used for the purpose; thus the feather will be riveted in its place, while the surface of the shaft will retain its roundness, because of the sides of the recess having been bulged as directed. After the feather is fastened, the surface of the shaft may be filed smooth and even.

Standing bolts or studs which are placed in a position liable to corrode them should have the standing ends $\frac{1}{8}$ inch larger than the nut end, and the plain part should be square. By this means a wrench may be applied to extract them when necessary, and the stud is not so liable to break off in consequence of weakness, at the junction of the thread, and the plain part where the groove to relieve the termination of the thread is cut.

Bolts that have become corroded in their holes so that they are liable to twist or break off in extracting them, should be well warmed by a red hot nut or washer, because the strength of the stud increases by being heated up to about 400° Fahr., and, therefore, studs which readily twist off when cold will unscrew when heated to about that temperature.

Nuts upon standing bolts in the smoke-boxes of locomotives or in similar positions, which have become so corroded as to endanger twisting the bolt off, should be cut through with a cape or cross-cut chisel, thus saving the stud at the expense of the nut. The split must be cut from the outside end face to the bedding face of the nut. To ease a nut that is a little too tight in the thread, screw it upon the bolt, and, resting it upon a block of iron, strike the upper side with a hammer, turning the nut so that not

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more than two blows will fall upon one face at a time, and striking light blows towards the last part of the operation.

To ease a nut that is too tight to its place to unscrew, so that an ordinary wrench will not move it, strike a few sharp blows on its end face; then, holding a dull-edged chisel firmly across the chamfer of the nut, strike the chisel-head a few sharp blows. Another plan is to put the full force of the wrench upon the nut, and strike at the same time the nut a few sharp blows upon its end face. If the nut is a large one, a piece of tube applied to the end of the wrench, together with blows struck on the end face, will often suffice to start the nut, especially if the nut is warmed.

Brass castings under 12 inches in size shrink about $\frac{1}{8}$ inch to a foot in cooling in the mould. Large castings shrink about $\frac{3}{16}$ inch.

To prevent air-holes in copper castings they should be moulded in green sand moulds, using as a flux $1\frac{1}{2}$ lbs. of zinc to every 100 lbs. of copper. Pure copper will not cast without honey-combing.

In casting iron or wrought-iron or steel spindles, the metal should be poured endwise of the mould, letting the cast metal cover the spindle an inch longer on the top end than is necessary. Thus the air-holes, if any, will form in the extra inch of length and may be cut off with it in the lathe.

Iron castings shrink in the mould about $\frac{1}{10}$ of an inch to the foot. The shrinkage sideways and endways of a casting 4 inches or less in size is compensated for by the shake in the sand given by the moulder to the pattern in order to extract it from the mould.

In very small castings requiring to be of correct size, allowance should be made in the pattern for the shake of the pattern of the sand, thus: A pattern to cast an inch cube will require to be made $\frac{1}{32}$ inch less than an inch endwise and sideways, and the usual allowance above an

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inch must be made on the top face of the pattern, which should have "top" marked on it.

TO ESTIMATE THE WEIGHT OF A CASTING FROM THE WEIGHT OF THE PATTERN.

A pattern weighing 1 lb. and made of	Will weigh when cast in Cast-Iron.	Zinc.	Copper.	Yellow Brass.	Gun Metal.
Mahogany	8	8	10	9.8	10
White Pine	14	14.5	18	17.5	17.8
Yellow Pine	13	12.6	16	15.5	16
Cedar	11.5	11.4	14.5	14	14.5
Maple	10	9.8	12.5	12	12.4

To soften copper, heat it to a low red heat and plunge it in salt water.

To clean the surface of copper, scour it with waste saturated with muriatic acid and fine sand, then wash off with clean water.

In riveting over the end of a gudgeon or crank-pin, apply the hammer first and the most around the outer circumference, which will prevent the riveted metal from splitting.

GRADES AND SPEEDS FOR EMERY WHEELS.

Diameter of wheel in inches.	Revolutions per min.	Number of emery.	Grade of cut.
2	5600	8 to 10	Wood-rasp.
4	3000	16 to 20	Rasp-file.
6	2000	24 to 30	Rough-file.
8	1500	36 to 40	Bastard-file.
10	1200	46 to 60	Second cut-file.
12	1100	70 to 80	Smooth-file.
14	900	90 to 100	Superfine-file.
16	750	120	Dead smooth-file.
18	700	... ...	...
20	600	... ...	...
22	550	... ...	...
24	500	... ...	...
26	450	... ...	...
30	400	... ...	...
36	325	... ...	...

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THREADS OF GAS OR STEAM-PIPES.

Inside diameter of pipe.	Threads per inch.	Inside diameter of pipe.	Threads per inch.
⅛ inch	27	1½ inches	11½
¼ "	18	2 "	11½
⅜ "	18	2½ "	8
½ "	14	3 "	8
¾ "	14	3½ "	8
1 "	11½	4 "	8
1¼ "	11½	Taper of threads	1-16 per inch of length.

To cut off the ends of bolts that were too long and have been turned down: Fasten a chisel in the vise with the cutting edge upwards, and rest thereon the end of the bolt to be cut off; then apply another chisel on the top of the bolt end, and strike as usual with the hammer.

Brass piston rings should have the split sufficiently wide to allow for expansion when hot; otherwise they will expand sufficiently to close up the split and bind in the cylinder, thus causing them to cut, or become cut by the cylinder. The same rule applies to brass piston heads.

Short screws or screws of small diameter, such as are usually cut by screw plates, should be cut as follows: Turn the screws as much too long as the thickness of the screw plate; then, for a distance from the end equal to the thickness of the screw plate, turn down the end of the screw so that it will nearly enter the screw plate without having any thread cut on it; and when the screw plate is applied to cut the thread, the reduced piece on the end will serve as a guide, keeping the screw plate true, the screw will then fit down evenly all round the underneath face of the head. This method is much more rapid and as true as that of finishing the threads in the lathe.

Piston rings should be turned inside as well as outside, so that they will not spring out of true when they are split. The time required to turn them inside is not one-tenth part of that required to true them in the vise, if they warp from being split.

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STEAM AND WATER JOINTS.

The best joint of any is the ground or scraped joint, but as this is for many purposes too costly, the following, based upon a lengthy practical experience, will be found reliable:

In fitting flanges to boilers or flanges together, be careful that the closest contact is around the hole. From the inside of the bolt-hole to the outside of a flange should be eased away a trifle whenever the bolts are standing bolts or are not liable to leak.

Red lead joints.—Take white lead ground in oil, and mix with it dry red lead sufficient to make it spread with a steel blade without sticking to it. Thorough bray the mixture by well hammering it with a hand hammer.

Gauze joints for high temperatures are easily made and are lasting. Fine iron gauze is cut to entirely cover the joint, and a coating of red lead mixed as above is laid over it. If the surfaces of the joint are very uneven, the gauze may be doubled.

For joints where hot or cold water are concerned canvas or duck may be used, having on it a coating of red lead mixed as above.

For ordinary joints combination rubber is an excellent material. It consists of alternate layers of rubber and canvas. When making such a joint, one of the surfaces of the rubber should be chalked to prevent the rubber from tearing if it becomes necessary to break the joint.

Rust joint.—Iron turnings 100 lbs., sal ammonia 1 lb., sulphur ½ lb. If the joint is required to set very quick add ¼ lb. more sal ammonia. The whole should be thoroughly mixed and just covered with water.

TO MAKE SPIRAL SPRINGS.

In selecting the material of which the spring is to be made we must bear in mind that unless the circumstances

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of the case necessitate that the spring be put to its utmost tension, brass will do as well as steel, and in fact better, providing the strain on the spring is *well within* its capacity, and possesses the advantage of being much more readily and easily made, since it requires no hardening or tempering. For heavy duty, however, or for duty where the spring is liable to be subject to high temperatures, brass is inadmissible. The steel used for spiral springs should be either spring or double shear steel. The wire used for brass springs is specially prepared by being sufficiently drawn without being annealed, which hardens the metal by closing its pores on the same principle that copper is hammer-hardened, that is to say, hardened by having its surface lightly hammered all over. For flat springs there is also manufactured a special cold rolled sheet brass, which may be easily distinguished by its rigidity and by its smooth and glossy appearance.

In using steel for springs we have the following considerations: If the springs when finished require to be polished, the polishing should be the first operation performed, because the surface of all hammered, rolled or drawn metals is closer grained at and toward the outer surface of the metal; and in the case of wrought-iron and steel, the outer metal is of better quality, and it is found in practice that steel retaining its forged, rolled or drawn surface, will make a stronger spring in proportion to its thickness, diameter and length, than those having a polished surface. It is also found in practice that the hardness of a tempered spring lies mainly at and near its surface, so that if we make a spring of the unpolished metal, and then polish it after it has been hardened and tempered, we shall find that it has lost in the polishing process a large proportion of its elasticity. It is much more difficult and expensive, as a general rule, to operate upon the surface of the metal after it has been formed into springs and tempered than it is upon the sheet metal or wire.

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If the wire of which the spring is to be made is too stiff and strong to be held by the hand against the mandril with sufficient force to cause it to bend closely around the mandril while the latter is slowly revolving, we must, if the lathe is a self-acting one, place upon it the gearing necessary to cut a screw of the pitch of the required spring, and then fasten in the tool-post of the lathe a piece of steel, having a half round groove (to suit the wire) cut in its end, so that after we have placed the wire in the hole of the mandril we may wind the grooved piece of steel, or pressure guide, as it may be more aptly termed, against the wire, and press the latter close to the mandril, in which case it is not necessary that the latter have any groove cut in it since the screw-gear will cause the spirals to be an even distance apart; in this latter case, however, the groove in the guide should be about half as deep as the diameter of the wire. If the lathe has no self-acting feed-gear, but has a slide-rest, we may take the winding-screw out of the rest and employ a mandril with a groove cut in it of the necessary pitch for the spring.

The mandril on which the spring is to be wound should have cut in it a spiral groove to suit the required spiral of the spring. At one end of the groove and about an inch from the end of the mandril there should be drilled a hole large enough to admit the spring wire. There should be provided a washer having a key-seat cut in it, the bore of the washer being large enough to pass over the spring when it is wound. The mandril should then have a driver put on it, and be placed in the lathe with the washer between the hole referred to and the end of the mandril, the hole end of the latter running on the dead centre of the lathe. The end of the wire should be placed through the hole referred to, the washer being between it and the dead centre, and the wire being (if of small size) held in the hand opposite to the groove and pulled tightly against the mandril, while the latter is slowly revolved in the lathe. When the

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spring is wound to the requisite length, the washer at the other end should be slipped over the spring to the end last wound and keyed on to the extreme end of the spring, the wire being pulled tightly against the mandril until the washer and key lock it; for if the wire was released before the spring was locked by the washer and key, it would partly unwind itself.

After the key is tightened the spring may be cut off by severing the wire outside of the washer.

If the spring requires to be hardened and of a correct diameter, the mandril should be taken to the fire and heated to a barely perceptible red heat, and left to cool with the washer on. If, however, it is not intended to harden the spring, as for instance when it is made of brass wire, we wind it just the same, and after it is wound and locked to the mandril by the washer and key, we take a light hammer and hammer it all over to the mandril as though we were forging it on the mandril, the object of which is to set it to the mandril, so that when it is taken off it will not open to a larger diameter, as it otherwise would do; it will, however, under any circumstances, open to a small extent when the washer is removed, and allowance should be made for this in the mandril by making its diameter smaller than the required finished size of the spring. To make a brass spring, special brass, called "spring brass," is indispensable, it being hardened by cold rolling.

HARDENING.

Spiral springs made of light wire, or those very long in proportion to their diameter, should be placed, before being heated, upon a mandril fitting closely to their bores, otherwise they are liable to become bent and their coils deranged during the heating process. The fire should be made of coked coal, that is, should not have any green or gaseous coal in it. It is a good plan to insert a piece of gas-pipe in the fire, and to heat the spring therein, which

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will insure, with ordinary care, by moving the spring back and forth in the tube or pipe, and also revolving it occasionally, that the spring be heated evenly all over. The spring, being heated to a cherry red, must be plunged perpendicularly and endwise into clean water having the cold chill taken off, and held therein until quite cold. If, on taking the spring from the water, the surface is dark-colored or only slightly mottled with white patches, it is in all probability not sufficiently hardened, which may arise from inferiority in the quality of the steel, or because it was not made sufficiently hot. Steel of good quality is sufficiently heated when hot enough to just form scales when taken from the fire. If it is found difficult to properly harden the steel (which may be known from the fact that steel well hardened presents when taken from the water a white surface having no black patches) the water should have salt in about the proportion of ½ lb. to the gallon added.

Here it may be noted that the whiteness of the surface is a better test of the degree of hardness of the metal than testing it with a file would be, because steel of a straw color in temper will be as impervious to file teeth as is the white hard steel, and therefore any degree of hardness between a straw color and a white hardness cannot be distinguished by the use of a file. Now the temper of a spring lowered from white hardness to a blue is not the same as that lowered from a black or even mottled hardness to a blue; and hence to obtain the nearest possible equality in the temper of springs, all those having, on leaving the water, after being quenched, a dark or even a mottled appearance, should be rehardened, because the existence of dark colors, even in small patches, upon the surface of either hardened steel or case-hardened iron, is evidence that the hardness is not that of the highest attainable degree; the deeper and more fanciful the colors the less the degree of hardness. To really test the hardness of metal

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with a file, we must take a good, dead smooth, or at least an ordinary smooth file, and apply one corner of it with great pressure to the work: a coarse file, even if a new one, is utterly useless to thoroughly test with.

TEMPERING.

The most reliable method of lowering or tempering an ordinary spring is to blaze it off—that is, to fry or boil it in the oil, the latter being sufficiently heated to cause it to take fire when brought into contact with a flame. After the spring has lain in the oil sufficiently to become thoroughly heated all through, it must be taken out and allowed to blaze, then dipped and blazed repeatedly, taking care that the oil does not burn off any one part. The thicker the spring the longer it should be blazed, so as to insure that the temper of the steel is equal all through. While the spring is being blazed off it should be reversed end for end, and revolved, especially when taken from the oil, and suffered to blaze, so that the blazing oil shall not run down along one side of the spring, and accumulate and blaze along the bottom, while the top, being bare and exposed to the ascending flames, will be made too soft. After the spring has been dipped and blazed frequently, it should be dipped finally in the oil, and while being revolved allowed to blaze until the blaze on any part of the spring goes out, when it should be dipped and cooled in lukewarm water, and the tempering is complete. A good oil composition for blazing is made in the following proportions: Spermaceti oil, one gallon; rendered beef suet, one pound; neats' foot oil, one gill; resin, one-quarter pound. The pan or tank in which this composition is used should have a closely-fitting cover, so that the blaze may be put out (when the tempering is finished) by putting the cover on.

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CHAPTER XV.

FITTING CONNECTING RODS.

THE planing work on a connecting rod being complete, the first thing for the fitter to do is to mark off the key-ways, the bolt holes (if there are any), the holes for the set screws, the oil holes, etc., so as to have the drilling completed before the straps or rod ends are filed up, because drills leave a burr where they come through the metal, and because the clamps, which hold the work while it is being drilled, are apt to leave marks upon it. The holes should then be tapped, when the rod will be ready for the file. The faces of the rod whereon the straps fit should then be surfaced with a surface plate, and made quite square with the broad faces of the rod, parallel crosswise with each other, and a little taper with each other in the length. The strap should be made narrower between its jaws than the width of the rod end, so as to require to spring open when placed upon the rod end if the brasses are not in their places. The inside faces of the jaws of the strap must be made quite square with the side faces, so that, when the strap is placed upon the rod end, the latter faces of the strap will not spring out true with the broad faces of the rod end. The rod end must have a light coating of marking rubbed over it, and the strap moved back and forth on it, so that the rod end serves as a gauge and surfacing-block to the strap.

If, when the strap is on its place, its side faces are uneven with the side faces of the rod end, as shown in Fig. 99 (which is a sectional view of a strap and rod end, *a* being the rod end, and B B the jaws of the strap), either one or

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both of the inside side faces of the strap require filing in the direction denoted by the dotted lines, because it is only in consequence of the inside faces not being square with the outside faces that this twist occurs. The keyways in the strap and rod end should be filed out together, that is, while the strap is on its place and secured by being clamped or bolted. If the strap is one held to the rod by a gib and key, the width, from the end of the rod to the crown of the strap when it is placed in position to cut or file out the keyway, should be that of the extreme width of the brasses when the joint of the brasses is close, less the amount of taper there is on the key.

Fig. 99.

The strap, after being fitted to the rod, should be clamped to the rod end, the keyway in the strap and in the rod being placed fair with each other, before the clamp is tightened, for moving the strap after it is clamped will spring it out of true, so that, when the clamp is taken off, the keyways will not be true with each other though they were filed true. In driving in the keys and gibs to fit them, be careful to put a light coat of marking on them, not only to show where they bind but to prevent them from seizing in the keyway. The key and gib placed edgewise together should be parallel on the outside edges, and the keyway should be parallel both edgewise and across its width. A thin sheet-iron gauge is better to measure the thickness of the keyway than inside calipers are, and the same gauge will do to plane the key and gib, leaving them a little full in the thickness. The keyways should be surfaced with a surface plate, its breadth being equal to that of the gib and key together when the head of the key is even with the head of the gib; then when the keyway is finished, and the strap is placed in its intended position on the end of the rod, the strap will have moved back from off the rod end for a distance equal to the amount of the taper on the key,

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so that there will be the requisite amount of draw on the keyway of the strap on the one side and on the keyway of the rod on the other side, while the key will at the same time come through the strap to its required distance. The faces of the rod end, whereon the jaws of the strap fit, having been made (as directed) a little taper, and the strap allowed (as described) a little spring, the rod end will enter the strap somewhat easily, and tighten as it passes up the strap, so that, when quite up, the strap will fit a little tighter than it is intended, when finished, to do. When the strap is fitted and keyed to the rod, a light cut should be taken off the faces of the rod and strap while they are together, the bolts of a bolt rod being sufficient to hold the strap for that purpose; but in the case of a gib and key, a piece of wood should be placed between the rod end and the crown of the strap, that is, in the space intended to be filled by the brasses, and the wood keyed up so as to lock the strap on the rod while the faces of the rod and strap are planed. This being complete, the strap is ready to receive the brasses. The bottom of back brass must be made to a tight fit, so as to spring the strap open sufficiently to make it fit the rod end as easily as required; thus both the brass and the strap will be closely fitted. The top brass must be fitted to the strap while the bottom brass is in its place in the strap, and must be made to fit the strap without being so tight as to spring it open. The corners of both brasses where they fit the corners of the strap should be eased away with the edge of a half-round file, so that they will not destroy the corners of the strap (when the brasses are being driven in and out to fit), which would make the strap appear to be a bad fit on the rod.

While fitting the top brass, it is necessary to try the strap on the rod end (the brasses being in their places) at intervals, so as not to take any more off the top brass than is necessary to let the strap fit the rod end. As a guide, when fitting the brasses to the strap, the calipers may be set to

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the width of the rod end where the strap fits, and applied to the strap when the brasses are driven in to fit. The gib and key must, when placed together edgeways, be quite parallel in their total breadth, so that they will fit properly against each other and against the keyway in the rod end and the strap. When setting the gauge for the size to which the brasses are to be planed, place the strap on the rod end to get the correct size, for the strap is narrower (between its jaws) when it is off than when it is on the rod, because of the spring. In bedding the black brass to the strap, let

Fig. 100.

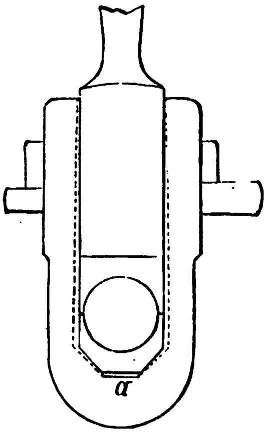
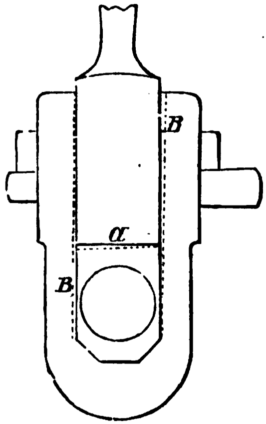


Fig. 101.



it bear the hardest, if anything, upon the crown, for if the bevels of the brass should keep the crown from bedding, the strap would spring away from the rod end, in spite of the gib (or the bolts, if there are any), when the key is driven home, as illustrated in Fig. 100.

If the back brass does not bed down upon the crown *a* of the strap, the latter will spring away from the block end of the rod and from the brasses on the sides, and will assume the shape denoted by the dotted lines. Should the top brass

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not bed properly against the rod end, the strap will spring as described in Fig. 101.

The dotted line *a* is the back of the brass, supposed to bed improperly against the rod end, as shown; the dotted lines B B denote the manner in which the strap would, in consequence, spring away from the rod end when the key was driven home. If the brasses fail to fit properly against the rod end or strap, in the direction of the breadth of the strap, it will spring out of line, as described in Fig. 102, which is a sectional view of a connecting rod end. C is the strap, D is the rod end, and B B are the brasses, the top one of which, if it did not fit square against the rod end (but on one side only), as represented by the line *a*, would spring the strap out of true with the rod end, in the direction of the dotted lines. The strap is, by reason of its shape, very susceptible to spring; and unless the brasses, or even the gib and key, are quite square and fit well, it is certain to spring out of true. The brasses should be a fit on the journal when they are "brass and brass," that is, the joint of the two brasses close together, so as to take the pressure of the key, which thus locks the strap and brasses to the rod end, and prevents them from moving, or working, as it is called, when the rod is in action; especially is this necessary in straps having a gib and key to hold them to their places, because, if the joint of the brasses is not close, the key cannot be driven home tightly, and hence there is nothing to lock the strap firmly to its place. If, however, the strap is held to its place by bolts, it is not so imperative to keep the joint of the brasses close together, although it is far preferable to do so, especially in the case of fast-running engines, not only on account of the assistance lent by the key to hold the strap firmly, but also because it holds the brasses firmly, and the key cannot bind the brasses too tightly to the journal, even though the key be driven tightly

Fig. 102.

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home, so as to assist the set screw in preventing it from slacking back.

The brasses should be left a little too tight in the strap before boring, because they invariably shrink or go in a little sideways from being bored, as do all brasses, large or small, even if bored before any other work has been done on them.

For driving the brasses in and out of the strap to fit them, use a piece of hard wood to strike on so as not to stretch the skin of the brass and alter its form, as already explained in the remarks on pening.

The brasses should be of equal thickness from the face forming the joint to the back of the brass, so that the joint will be in the centre of the bore of the brasses. The respective faces forming the joint should be quite square with both the faces and sides of the brass, so that they will not spring the strap when they are keyed up, and so that, when the brasses are let together in consequence of the bore having worn, the faces may be kept square, and thus be known to fit properly together without having to put them together in the rod and on the journal to try them, which would entail a good deal of unnecessary labor.

To get the length of a connecting rod, place the piston in the centre of its stroke, and the distance from the centre of the crosshead pin to the centre of the crank shaft is the length of the rod from centre to centre of the brasses. Another method is to place the piston at one end of its stroke and the crank on its dead centre corresponding to the same end of the stroke, and the distance from the centre of the crosshead pin to the centre of the crank pin is the length of the rod.

To ascertain when the crank of a horizontal engine is upon its exact dead centre, strike upon the end face of the crank axle or engine shaft a circle true with the shaft, and of the same diameter as the crank pin: then place a spirit level so that one end rests on the crank pin and the other

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end is even with the outline of the circle; and when the spirit level stands true, the crank will be upon its dead centre.

The length of a connecting rod cannot be taken if the crank is placed in the position known as full power, because the position in which the piston would then be cannot practically be definitely ascertained; for the angle at which the connecting rod stands causes the piston to have moved more or less than half the length of the stroke when the crank has moved from a dead centre to full power, according to which end of the cylinder the piston moved from. If it was the end nearest to the crank, the piston moved less, if the other end, it moved more, than half of its stroke; so that in either case the piston stands nearer the crank than is the centre of the length of the cylinder when the crank is in the position referred to. This variation of piston movement to crank movement is greater in the case of short connecting rods than with long ones.

To fit a connecting rod to an engine, first rub some marking on the crank pin, and put the crank pin end of the rod on its place, with the brasses in and keyed properly up. The other end of the rod, being free, can be placed so as to touch against the crosshead pin, when the eye will detect if it will go into its place without any spring sideways; if it will do so, the rod may be taken off the crank pin, and the brasses, if necessary, fitted to the pin sufficiently to allow each to bear on the crown. But if the rod end will not fall into the crosshead journal without being sprung sideways, then move it clear of the crosshead, placing a side pressure on it in the direction in which it wants to go to come fair with the crosshead journal, and move it back and forth under such side pressure, which process will cause the crank pin to mark where the connecting rod brasses want filing and scraping to bring the rod true. The rod must then be taken off, and the brasses

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eased where the marking and the knowledge of which way the rod ought to go determine, the rod being placed on the crank pin as before, and the whole operation repeated until the rod "leads" true with the crosshead journal. The crosshead end of the rod must be fitted in like manner to the crosshead journal until the crank pin end of the rod leads true to the crank pin journal. The rod must then be put on its place, with both journals keyed up, and, if it can easily be accomplished, the engine moved backwards and forwards, the brasses being then taken out and bedded, when the rod will be fitted complete. A connecting rod which has both straps held by gibs and keys gets shorter from centre to centre of the bore of the brasses as it wears, and that to half of the amount of the wear. This is, however, generally rectified by lining up the brasses—that is, placing pieces of metal behind them (they may be fastened to the brasses if it is desirable)—which pieces are made of the required thickness to replace the amount of the wear of the brasses.

A connecting rod whose crosshead end has a strap with a gib and key, or, what is better, two gibs and a key, to hold it, the crank pin end having its strap held by bolts, and the key between the bolts and the brass, would maintain its original length, providing the wear on the crosshead brasses was as great as is the wear on the crank pin brasses; but since that on the latter is the greatest, the rod wears longer to half the amount of the difference of the wear between the crosshead and crank pin journals. If both the straps of a rod are held by bolts, the key of one end being between the brasses and the main body of the rod, and the key of the other end between the brasses and the crown of the strap, it would maintain its original length if the wear on both ends was equal; but this not being so, it wears longer, as above stated. When marking off the end of the rod (that is, the circle on the brasses to set them by for boring), or when trammeling a rod to try

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its length, stand it on its edge; because if it rests on its broad face the rod will deflect, and appear to be shorter than it is; this is especially liable to occur in coupling or side rods, which are generally longer and slighter in body than connecting rods.

The oil hole of a strap for either a connecting or side rod should be in the exact centre of the space intended to be filled by the brasses. It will thus be central with the joint of the brasses, and from centre to centre of the oil holes, and will, therefore, represent the proper length of the rod. When, therefore, the brasses of a rod end whose strap is held by a gib and key, have worn so that the key is let down, the brasses must be lined up to bring the key back to its original position, the back brass being lined up so that its joint face comes even to the centre of the oil hole, and the other brass being lined up sufficiently to bring the key back to its original position; then the rod is sure to be its proper length. But if the strap is held by the bolts (in which case it does not move when the brasses are let together and the key further through), lining the back brass up to the centre of the oil-hole at once insures the rod being of its correct length, without any reference as to what thickness of liner is put on the other brass, or how far the key may come through. In either case it will be observed that the centre of the oil-hole, when placed as described, forms a gauge to keep the rod its proper length. To ascertain what thickness of liner is required for the brass back, place it in its place in the strap, and scribe a line (on the inside of the strap) even with the joint face of the brass; then mark a line across the strap so that the line will intersect the centre of the oil-hole, and the distance between the two lines will be the requisite thickness of liner.

To find the thickness of liner necessary to the other brass, put the strap in its place with both brasses in, and the back one lined up; then key the brasses up, and scribe

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a line on the key at its narrowest end, even with the face of the strap; then the difference between the width of the key (on the taper face) at the line (which is the distance it does come through), and the width of the key at or near the narrow end (that is to say, the distance it ought to come through), is the thickness of liner required.

DRIFTS.

Of drifts there are two kinds, one being a smooth round conical pin, employed by boiler makers to make the punched holes in boiler plates come fair, so that the rivets may enter, which may be aptly termed a stretching drift, and the other the toothed or cutting drift. Of the first, it may truly be said that it is utterly destructive of the safety of any work to which it is applied, because the punching of a plate considerably weakens its strength at the narrowest section of metal, namely, between the hole and the edge of the plate, where the latter, being the weakest, gives way to the pressure of the punch. If one closely observes the surface of a piece of iron which is being punched, he will find that the scale on the surface of the iron round the hole, and especially between the hole and the edge of the plate, will be sensibly disturbed, showing a partial disintegration of the grain of the metal beneath, even if the punch is very sharp; but if the punch is dull, or the edge is in the least rounded by wear, the scale will fly off the surface of the metal in small particles, evidencing a considerable disturbance of the metal beneath and an equivalent weakening of the substance between the edge of the hole and the edge of the plate. If, then, after punching, the holes do not come fair, and the plain drift is employed to still further stretch the metal, not only is the weakening process greatly augmented, but the holes are stretched oval, so that the rivets do not completely fill them, however well the riveting may be performed. The use of the plain drift is therefore totally incompatible with first-class work-

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manship; hence a description of this tool will be altogether omitted.

Of cutting drifts, there are two kinds, the first being that shown in Fig. 103. A is the cutting edge, the width and thickness at C and B being reduced so that the sides of the drift may clear the sides of the hole. The tools are filed at A A, to suit the required hole, and tempered to a brown bordering upon a purple. The hole or keyway is then cut

Fig. 103.

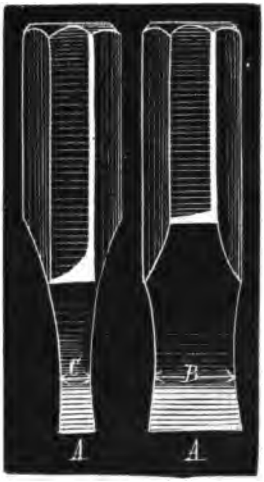

Fig. 104.

out roughly, to nearly the required size, and the drift is then driven through with a hand hammer, cutting a clean and true hole. Care must, however, be taken to have the work rest evenly upon a solid block of iron or (for delicate work) lead, and to strike the punch fair and evenly, otherwise a foul blow may break the drift across the section at C. This class of drift is adapted to small and short holes

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only, such as cotter ways in the ends of keys or bolts, for which purposes it is a very serviceable and strong tool. It must be freely supplied with oil when used upon wrought-iron or steel.

For deeper holes, or those requiring to be very straight, true, and smooth, the drift represented by Fig. 104 is used. The breadth and thickness of the section at A is made to suit the shape of the keyway or slot required. The whole body of the drift is first filed up parallel and smooth, to the required size and shape; the serrations forming the teeth are then filed in on all four sides, the object of cutting them diagonally being to preserve the strength of the cross section at A A. The teeth may be made finer, that is, closer together, for very fine work, their depth, however, being preserved so as to give room to the cuttings. To attain this object in drifts of large size, the teeth should be made as shown in Fig. 104, which will give room for the cuttings, and still leave the teeth sufficiently strong that they do not break. The head B of the drift is tapered off, so that, when it swells from being struck by the hammer, it will still pass through the hole, since this drift is intended to pass clear through the work.

The method of using this tool is as follows: The hole should be roughed out to very nearly the required size, leaving but a very little to be taken out by the drift, whose duty is, not to remove a mass of metal, but to cut a true and straight hole. To assist in roughing out the hole true, the drift may be driven lightly in once or twice, and then withdrawn, which will serve to mark where metal requires to be removed. When the hole is sufficiently near the size to admit of being drifted, the work should be bedded evenly upon a block of iron or lead, and oil supplied to both the hole and the drift; the latter is then driven in, care being exercised that the drift is kept upright in the hole. If, however, the hole is a long one, and the cuttings clog in the teeth, or the cut becomes too great,

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which may be detected by the drift making but little progress, or by the blow on the drift sounding solid, the drift may be driven out again, the cuttings removed, the surplus metal (if any there be in the hole) cut away, the hole and drift again freely oiled, and the drift inserted and driven in as before, the operation being continued until the drift passes entirely through the hole; for the drift will be sure to break if too much duty is placed upon it. After the drift has passed once through the hole, it should be turned a quarter revolution, and again driven through, and then twice more, so that each side of the drift will have contacted with each side of the hole (supposing it to be a square one), which is done to correct any variation in the size of the drift, and thus to cut the hole true.

The great desideratum in using these drifts is to drive them true, and to strike fair blows, otherwise they will break. While the drift is first used, it should be examined for straightness at almost every blow; and if it requires drawing to one side, it should be done by altering the direction in which the hammer travels, and not by tilting the hammer face (see Fig. 105).

Suppose A to be a piece of work and B and C to be drifts which have entered the keyways out of plumb, as shown by the dotted lines D and E. If, to right the drift C, it was struck by the hammer F, in the position shown and travelling in the direction denoted by G, the drift C would be almost sure to break; but if the drift B was struck by the hammer H, as shown, and travelling in the direction denoted by I, it would draw the drift B upright without breaking it; or in other words, the hammer face should always strike the head of the drift level and true with it, the drawing of the drift, if any is required, being done by the direction in which the hammer travels. When it is desired to cut a very smooth hole, two or more drifts should be used, each successive one being a trifle larger in diameter than its predecessor. Drifts slight in

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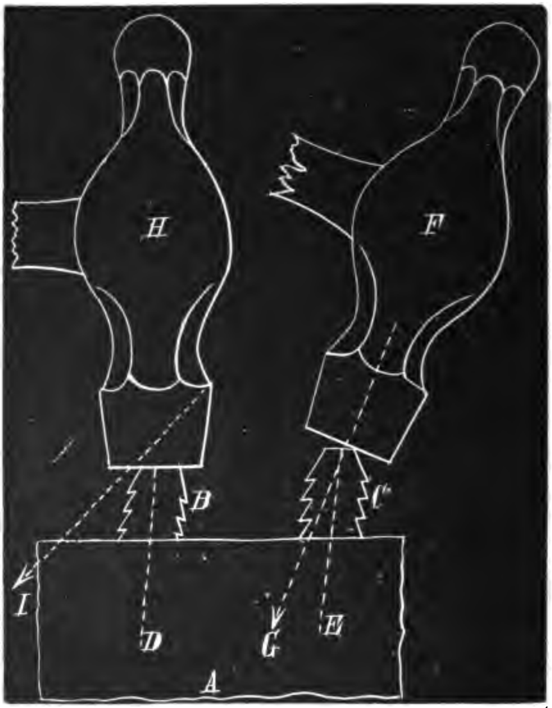
cross section, or slight in proportion to their lengths, should be tempered evenly all over to a purple blue, those of stout proportions being made of a deep brown bordering upon a bright purple. For cutting out long narrow holes, the drift has no equal, and for very true holes no substitute.

Fig. 105.



It must, however, be very carefully used, in consequence of its liability to break from a jarring blow.

REVERSE KEYS.

Crossheads, pistons, and other pieces of work which are keyed to their places upon taper rod ends, and are therefore

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apt to become locked very fast, are easily removed by means of reverse keys, which should always be employed for that purpose, because striking such work with a hammer, even supposing the work to be well supported underneath and copper interposed between the hammer and the work, is liable to bend and otherwise damage it with every heavy blow.

Reverse keys are simple pieces of steel, so shaped as to reverse the draft of a keyway, and are made male and female, as shown in Fig. 106, A representing the male, and B the female. The manner of using them is to insert them into the keyway, as shown in Fig. 107, in which A

Fig. 106.

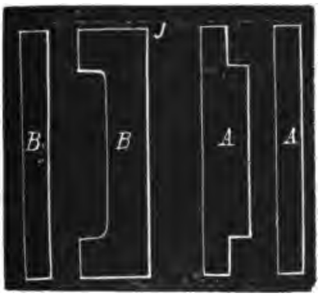
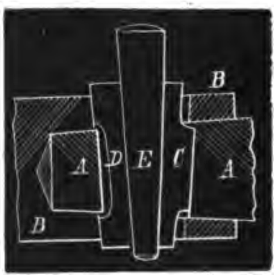


Fig. 107.



represents a taper rod end, B the socket into which A is fitted or keyed, C the male and D the female reverse key, and E an ordinary key. It will be found, on examination, that the insertion of C and D have exactly reversed the position of the draft of the keyway, so that the pressure due to driving in the key will be brought to bear upon the rod on the side on which the pressure was previously on the socket, and on the socket on the side on which the pressure was on the rod; so that driving in the key will key the socket out of instead of into its place.

The keyway in Fig. 107 is shown to have draft; that is, the proper key, when driven in, will bear one edge upon

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the edge of the keyway in the rod only, and not on the edge of the keyway in the socket at the small end of the cone; while at the large end, the natural key would bear against the edge of the keyway in the socket only. If, however, this condition does not exist, and the edges of the key bear equally upon the cone and the socket (on both edges and all the way through), the keyway being a solid one, that is to say, having no draft, the reverse keys may be employed, providing that C is placed so as to bear upon the edge of the keyway on the large end of the cone only, and that D is placed to bear on the edge of the keyway at the small end of the cone on the socket only, thus producing a back draft, or clearance, as it may better be termed. The key E should be made long, and both it and the reverse keys should be made of steel and left soft.

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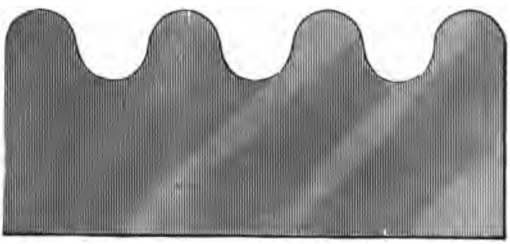
CHAPTER XVI.

MILLING-MACHINES AND MILLING-TOOLS.

THE position occupied by the milling-machine in modern practical mechanics is almost as important as that occupied by the lathe or planing-machine. In getting out work by the aid of either of the latter, the size and uniformity of the work depend upon the accuracy in measurement, and hence upon the skill of the operating artisan, hence a skilled and expert workman is necessary to the use of each lathe or planer. In the case, however, of a milling-

Fig. 108.



machine, the skilled mechanic has but to properly set the machine and the chucks necessary to hold the work, and a less skilful operator may be assigned to continue the operation of getting out any number of similar pieces of work, with the assurance that uniformity of size and form and equality of finish may be, with ordinary care, assured. Then, again, intricate forms and shapes of work may be exactly and easily duplicated by the employment of

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milling-tools, which would be impracticable were the same work operated upon by a planing-machine; especially is

Fig. 110.

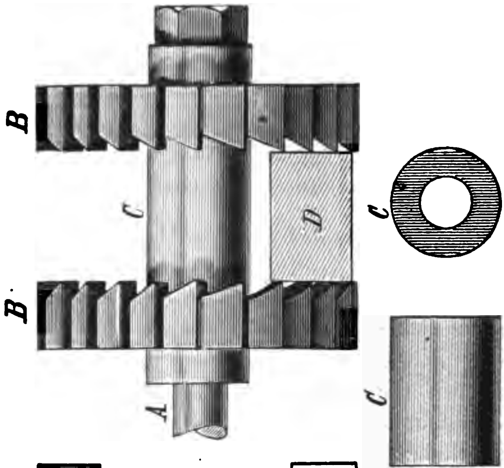
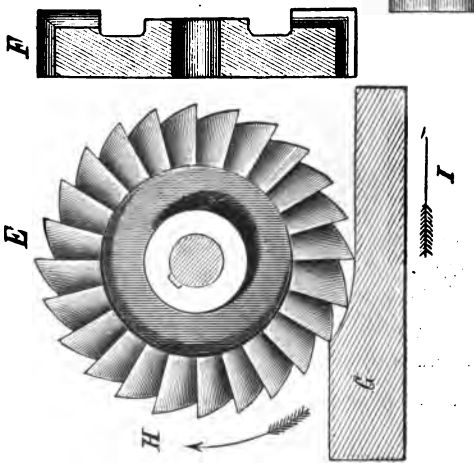


Fig. 109.



this the case in work of complicated form. Suppose, for instance, it were required to cut out a corrugated surface, such as shown in Fig. 108, it would be a difficult matter to produce, with a planing-machine, one such a piece of work

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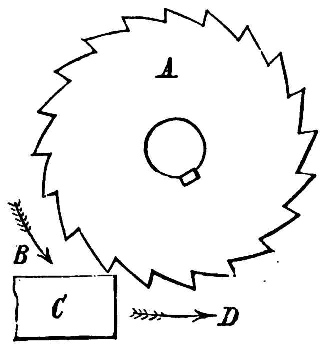
quite true and with a smooth and polished surface, because the tool would be liable to spring from the broadness of cutting surface, which would, in the case of wrought-iron and steel, cause the tool to spring into the softer and away from the harder parts of the metal; and in the case of any metal it would be quite difficult to feed the tool so as to insure exactitude and avoid tool-marks at the junction of the cuts taken by the round-nosed and curved tools; whereas, with a milling-tool, properly made (and it is no difficult matter to make such a tool), the operation is so simple that it may be performed with comparatively unskilled labor.

Fig. 111.



One of the main advantages of milling-tools is that the work will, in nearly all cases, be true, even, and smooth, even though the tool itself be a little out of true.

Suppose, for example, we require to mill the side faces of a rod, and we employ for the purpose the milling-bar and cutters shown in Fig. 110, in which A represents the spindle of a milling-machine, and B B are milling-cutters with the distance washer C interposed between them to regulate their distance apart; D representing a piece of work being fed between the revolving cutters B B. Now, it is evident that even were the cutters out of true, the pieces of work would all be cut to one size, because the projecting teeth of the cutters will come into contact with and operate upon each part of the surface of the work being operated upon, the only difference being that the work will be cut narrower with the same thickness or length of washer than it would be were the washers true.

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In Fig. 109, E represents a view of the face of a milling-cutter, and F a sectional view of the same, while G represents a piece of work passing under the cutter and not between the cutters, as shown in the case of the work D. The arrow H denotes the direction in which the cutter E would require to revolve, and the arrow I the direction in which, in that case, the work would require to travel; from which it will be perceived that the lateral strain placed upon the work by the cut is in a direction to force the work back from the cutter, and this must always, in the use of milling-tools, be the case, and is a very important consideration for the following reasons:

From the breadth of cut taken by a milling-tool, and from the acute angle at which the teeth of the cutter strike the cut when the work passes below the circumference of the cutter, the strain due to the cut is immense; and were this strain in a direction to drag or draw the work below or towards the cutter, the latter would, from the spring of the spindle, rip into the work and tear its own teeth off. Thus, in Fig. 111, suppose A to be a milling-cutter revolving in the direction of the arrow B, and C to be a piece of work travelling in the direction of D, it will be readily perceived that there will be an enormous strain in a direction to force the work from its chuck or clamps and drag it under the cutter.

The work being held sufficiently firm, cannot, it is true, move in that direction faster than the rate of feed will permit; but the teeth grip the work, the cutter springs forward and attempts to ride like a spiked wheel over the work, and the cutter-teeth break from the undue pressure; and therefore it is that in milling work of every kind whatsoever, the direction in which the work is fed should be such as to tend to force the work away from the cut; or, in other words, the cutters should cut under the cut, not only because of the above imperative reasons, but for the following additional ones:

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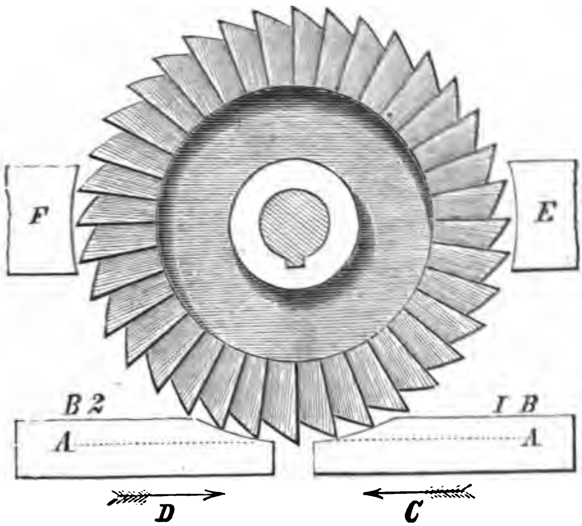
The skin of iron or brass castings and of iron or steel forgings is considerably harder than is the interior of the metal, in addition to which there is frequently scale in the one case and sand in the other to contend with, so that if the cutting edge of a tool comes into contact with the outer skin of the work, the keenness, and hence the cutting value of the tool or cutter, becomes rapidly impaired; and milling-cutters being expensive tools to make, it is desirable that their cutting edges and qualifications be preserved as long as possible. Suppose, therefore, that in Fig. 112 from A to B represents the depth of cut on two

Fig. 112.



pieces of work, one travelling beneath the cutter in the direction of the arrow C, and the other in the direction of the arrow D, and that the upper surfaces B, in each case, have a hard surface-skin upon them: it becomes apparent then that in the case of the piece represented at 1, the cutter-

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teeth will, after the cut has once started, meet the soft metal and cut under the skin till the cut has ended, so that, save at the very commencement of the cut, the cutter-teeth would never meet or come into contact with the hard surface-skin; while in the case of the piece of work 2 the teeth would in every instance strike the hard skin first. If the piece of work E were held in the position shown, it would strike the scale, whichever way the cutters ran or the work was fed; and the same remark applies to the piece of work F. There is this difference, however, between the two latter positions: with the cutter revolving in the direction shown, the strain of the cut would be in a direction to lift E from the machine-table, rendering it very liable to spring and difficult to cut; while the strain on F would tend to force it down upon the table, which would be far preferable.

When the side faces of the cutters operate, they must be made right and left—that is to say, the teeth of one cutter must slope in the opposite direction to those on the other cutter, so that when the two are placed opposite to one another, as shown in Fig. 110, the teeth of both will stand in a direction to accommodate the direction in which the cutters revolve. To cut side faces of any required width, we have only to vary the width apart of the cutters by the washer C, in Fig. 110; while, to cut curves and shoulders, the periphery only of the cutters can be used. Thus, suppose it were required to cut out the form shown in Fig. 113, the outline of the cutter would require to be as shown in Fig. 114, but it would be a tedious and difficult matter to get up a solid cutter of such a shape on account of the difficulty of cutting the teeth; hence, all such compound forms are produced by making separate cutters, each of its requisite form, size and width, and then placing them together to make up the whole. Thus the figures from 1 to 8 each represent a separate cutter. It is obvious then that there is scarcely a limit to the forms capable of being

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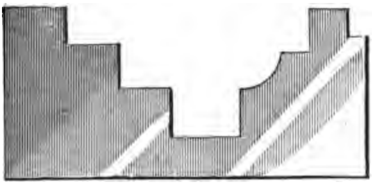
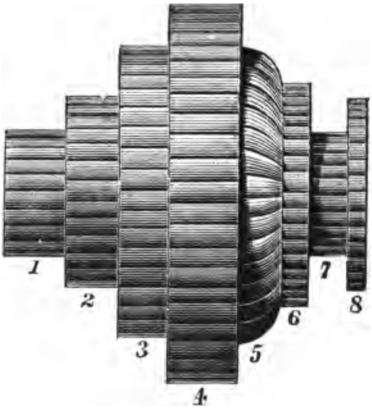
smoothly cut and uniformly reproduced by such cutters. The Morse Twist Drill Company cut the threads upon their taps, and give the sides of threads a slight amount of clearance back from the cutting edges by the use of milling-tools, producing a tap equal in every respect to those producible in the lathe, and being remarkable for uniformity of size and finish.

Fig. 113.



Milling-cutters of small size are made of solid cast-steel; for larger sizes, the body is made of wrought-iron, while the faces whereon the cutting-teeth are to be formed have steel welded on them.

Fig. 114.

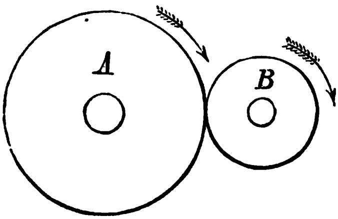


After the cutters are bored and turned to the requisite size and shape, the spaces necessary to the formation of the teeth may be cut by a milling-cutter; and here it may be well to note that it is advisable to keep the teeth sufficiently wide apart to give plenty of room for the cuttings to escape; even in cutters for gear-wheels, coarse teeth—that is, those wide apart—will cut quicker and smoother than fine ones, and have the advantage that they entail much less labor in both the manufacture when new and resharpening when dull. After the spaces are cut out and

the teeth formed, the cutting edges must be carefully filed up and the cutter hardened. If, however, the faces of the cutters are plain and the spaces between the teeth are sufficiently wide to admit of the teeth being ground by an emery-wheel (as is usually the case, and as should be the case whenever it is possible), the sharpening process should be performed as follows:

The cutter, after being hardened, should be revolved rapidly in the lathe in one direction, while an emery-wheel revolves at a high speed in the opposite direction, as shown in Fig. 115, A representing the cutter and B the emery-wheel; the emery-wheel should be fed to the cutter just sufficient to true the cutting edges, after which the necessary clearance and sharpening may be given to the teeth as follows: Beneath a revolving emery-wheel, and quite parallel and true with the spindle on which the emery-wheel revolves, there is provided a stationary adjustable mandril of such a size as to neatly fit the centre hole in the cutter to be operated upon; which mandril is of a sufficient length to permit the cutter to slide along it and stand wholly on either side of the emery wheel. The height of the mandril is adjusted so that the emery-wheel will, when brought into contact with the cutter (while the latter is upon the mandril), take off just sufficient to sharpen and give clearance to the teeth. It is obvious, however, that some guide is necessary to insure that the teeth of the cutter shall pass under the emery-wheel in the necessary and in an exactly uniform position, which object is accomplished by providing an adjustable stationary guide or gauge, against which one of the teeth of the cutter shall slide while the other is being

Fig. 115.



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ground. The operation is thus to place the cutter on the mandril and adjust the latter to the requisite height, to then adjust the guide so that when the cutter is moved forward it will first come into contact with the guide, against which the cutter is held by the hand, while it is at the same time passed under the emery-wheel. It is obvious that by this means either circumferential or side face teeth may be sharpened and maintained true if the bearing of the cutter upon the mandril is sufficiently long and of sufficiently accurate fit to keep the cutter steady. There are other devices for large cutters in which the latter are stationary and the emery-wheel traverses along the teeth, which plan is for large cutters preferable to that first described; the principles involved are, however, the same in both cases.

It must be remembered that, in using the emery-wheel for this purpose, it *must* run under its cut for the reasons already explained by Fig. 111 and its accompanying explanation.

It is obvious that in the case of long cutters having circumferential teeth, the excessive strain due to each tooth striking the cut will cause the mandril carrying the work to spring away from the cut, the effect being that the finished surface of the work will be slightly waved. To remedy this defect, the teeth of the cutter should be made to run slightly spiralled, and not straight across the length of the cutter, so that the cutting edges will be taking and leaving the work continuously, and hence the spring above referred to will be at all times equal. The same object is obtained in compound cutters, such as shown in Fig. 114, by cutting the key or feather-ways in the cutters, so that their teeth will not stand in a line one with the other.

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CHAPTER XVII.

TO CALCULATE THE SPEED OF WHEELS, PULLEYS, ETC.

MULTIPLY the speed of the driving-wheel by the number of teeth it contains, and divide by the speed required by the driven wheel.

Example 1.—If a wheel contains 50 teeth and makes 25 revolutions per minute, what number of teeth must a wheel contain to gear into it and make 125 revolutions per minute?

$50 \times 25 = 1250 \div 125 = 10.$ *Ans.* 10 teeth.

Example 2.—A wheel contains 90 teeth and makes 128 revolutions per minute, how many teeth must a wheel contain to gear into it and make 260 revolutions per minute?

$90 \times 128 = 10800 \div 240 = 45.$ *Ans.* 45 teeth.

Example 3.—A wheel contains 45 teeth and makes 240 revolutions per minute, how many teeth must a wheel geared into it contain to run 128 revolutions per minute?

$45 \times 240 = 10800 \div 128 = 90.$ *Ans.* 90 teeth.

In the case of pulleys or band-wheels the rule is the same, except that the diameter of the wheel is taken instead of the number of teeth.

Example 1.—A driving-wheel makes 120 revolutions per minute and is 24 inches in diameter, what size pulley must I employ to obtain 60 revolutions per minute?

$120 \times 24 = 2880 \div 60 = 48.$ *Ans.* 48 inches.

Example 2.—A driving-wheel four feet in diameter makes 245 revolutions per minute, what size pulley must I use to obtain 45 revolutions?

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Diameter of wheel in inches.

$48 \times 245 = 11760 \div 45 = 248.$ *Ans.* 248 inches.

Example 3.—A driving-wheel makes 182 revolutions per minute, and is 15 inches in diameter, what size pulley do I require to make 145 revolutions?

$182 \times 15 = 2730 \div 145 = 18.965.$

Ans. A pulley 18 $\frac{96}{100}$ in. in diameter.

Another rule which will answer, whether we employ a single pair or two pair of pulleys, is as follows:

Divide the speed you require to run by the speed of the driving-shaft, and the quotient will be the proportion between the revolutions of the driving-shaft and the revolutions required. Then take any two numbers that will, when multiplied together, form a sum equal to that proportion, and one of such numbers will form the relative sizes for one of the pairs of pulleys, and the other of such numbers will form the relative sizes for the other pair of pulleys.

Example.—It is required to run a machine 1200 revolutions per minute, the driving-shaft makes 120 revolutions per minute, what sizes of pulleys shall be used?

Revolutions required.		Revolutions of driving-shaft.	Proportion of speed.
1200	$\div$	120	$= 10$
Then 5	$\times$	2	$= 10$
or 4	$\times$	$2\frac{1}{2}$	$= 10$
or $3\frac{1}{3}$	$\times$	3	$= 10$

So that the proportion being ten to one, we may use two wheels of any sizes, providing that the one on the driving-shaft is ten times as large as the one on the machine: or since $5 \times 2 = 10$, we may place on the driving-shaft a pulley, say five feet in diameter, and belt it to one a foot in diameter, forming the proportion between the first pair of pulleys of five to one. Our next pair of pulleys must

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be two to one, that is to say, we may use a two foot and a one foot pulley, a four and a two foot, or any others, so that one is twice as large as the other. Or again, since $4 \times 2\frac{1}{2} = 10$, we may use a four foot pulley, or the driving-shaft belted to a foot pulley, or a 24 inch one belted to a 6 inch one, the proportion in either case being 4 to 1, then for the second pair we may employ a 12 and a 6 inch, or a 24 and a 12, or any two pulleys we may have on hand, so that one is twice as large as the other. It is obvious that when the speed required is greater than that of the driving-shaft, the large pulleys are the driving and the small ones are the driven pulleys.

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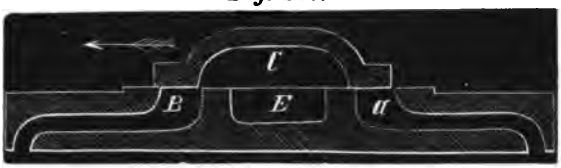
CHAPTER XVIII.

THE SLIDE VALVE.

THE common slide valve is a simple deviçe for regulating the ingress and egress of steam to and from the cylinder, as illustrated in Fig. 116. It is here shown in

Fig. 116.



the position in which it would be when the piston of the engine had moved to the end of one stroke and was prepared to commence the next, *a* being the port through which the steam is passing into the cylinder, and B the port through which the steam which propelled the piston on the previous stroke must now find egress.

The valve C is moving in the direction of the arrow, so that the port *a* is left open for the steam to enter as the valve recedes from it, and a free communication is at the same time being established between the port B and the exhaust port E of the cylinder, thus permitting the steam to escape through E.

When the piston has arrived at the other end of the cylinder, the valve C will have moved back, so that these conditions will be exactly reversed, B being the port through which the steam will then enter, and *a* that

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through which the exhaust steam will escape from the cylinder.

The lead of a valve is the width of opening which the valve permits (by reason of the position to the crank in which the eccentric is set) to the steam port when the piston is at the end of the stroke, as shown in Fig. 116, at the port *a*.

If the valve were set so that it had no lead, both the ports *a* and B would be closed by the valve, so that the steam could neither enter nor leave the cylinder until the momentum of the fly-wheel had caused the crank to pass the dead centre, and therefore the valve to open.

Lead is given to a valve to enable the steam to act as a cushion upon the piston, by admitting the steam to it before it has arrived at the end of its stroke, thus causing it to reverse its motion easily and without noise.

If the working parts of an engine have much play or lost motion in them, the steam admitted by lead will, by opposing a gradual force in a direction opposite to that in which those parts are moving, take up such play before the piston has reversed its motion, and therefore more gradually and less violently than would be the case if the force of the steam came upon the piston at the instant at which it reversed its motion. In the latter case the piston, after reversing its motion, would have no load against it until the play of the working parts was taken up, so that it would travel very fast during the instant of time in which such play was being taken up; and the check, given to it on meeting its load again, would cause a thump or pound to the piston. But if the working parts are a reasonably good fit, and the valve has lap on it to give a free exhaust, there appears no necessity for giving the valve more lead than is sufficient to about fill the steam passage and the clearance (that is, the space between the cylinder cover and the piston when the latter is at the end of its stroke) with steam at full pressure, by the time the

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piston arrives at the end of the stroke: the object of lead to this amount being to supply steam at full pressure to the piston from the instant the crank has passed its dead centre and the piston has commenced its stroke, and at the same time to prevent any unnecessary amount of back pressure, for the steam admitted by lead acts at all times as a back pressure upon the piston; so that, if the valve has too much lead, not only is there a consequent loss of power from back pressure, but the piston receives a sudden and violent shock, which is sure in the end to result in damage to some part of the engine, such for instance as loosening the piston upon the rod, or either loosening or breaking the crosshead pin or the crank pin.

It must be borne in mind that, as the steam admitted by lead commences to enter the cylinder before the piston has arrived at the end of its stroke, if the amount of lead is so great as to admit sufficient steam to the steam passages and cylinder, and to fill them at full pressure before the piston has arrived at the extreme end of its stroke, the advancing piston will have to force or pump part of such steam back again into the steam chest. Engines whose cylinders are vertical and above the shaft are given more lead on the bottom than on the top of the cylinder, because the wear of the various moving parts of the engine is mostly downwards and away from the cylinder, so that the lead becomes more on the top and less on the bottom as the engine wears. If, however, the cylinder is vertical and below the shaft, these conditions are exactly reversed.

The steam lap of a valve is the amount by which it exceeds the extreme width of the cylinder ports, as illustrated in Fig. 117, from *a* to B being in each case the lap.

By means of giving steam lap to the valve, the engine is enabled to use its steam expansively, that is, the valve cuts off the supply of steam to the piston before the latter has travelled to the end of the stroke, as shown in Fig. 118, in which the valve is shown as having just closed the port C,

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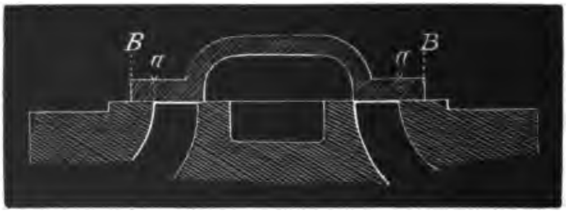
the direction in which the piston and valve are respectively moving being denoted by the arrows.

Lap on the exhaust side of a valve is a subject to be hereafter treated upon. The advantage derived by using steam expansively may be perceived by supposing the stroke of a piston to be 9 inches, and the steam supply to be cut off by reason of the lap on the valve when the piston has travelled 6 inches; it will then have to travel the remaining 3 inches of stroke, receiving only such pressure as the steam already in the cylinder will impart. The pressure of steam increases or diminishes in exact ratio to the space it occupies, the temperature being

Fig. 117.



maintained equal; that is to say, if the steam occupying 1 cubic foot at a pressure of 50 pounds is permitted to expand its volume so that it occupies 2 cubic feet, its pressure will decrease to 25 pounds; but if it were compressed so as to occupy one-half of a cubic foot, its pressure would rise to 100 pounds.

In Fig. 118 the steam would occupy that portion of the cylinder from *a* to *b* (that is, 6 inches of its length, supposing the whole length to be 9 inches), at a pressure of, say 50 pounds per inch. When, therefore, the piston has moved another inch, the steam will occupy $\frac{1}{7}$ more space (that is, 7 inches instead of 6 inches of the length of the cylinder), thus reducing its pressure by $\frac{1}{7}$, bringing it down from 50 to 42.86 pounds per inch, and so on.

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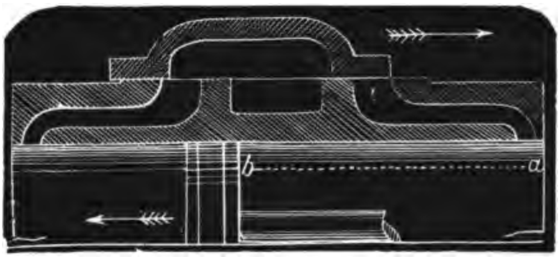
During the first 5 inches of the travel of the piston, the steam port is open, and the full pressure of the steam is continuously exerted to move the piston; but at the sixth inch, the steam lap on the slide valve closes the port. Going now to the seventh inch, we find one-seventh more space between the piston and the cylinder head, while there is only 6 inches of steam at normal pressure; and so we have one-seventh less pressure, or 42.86 pounds. At the eighth inch, the space and the steam are still more disproportionate, there being one-fourth more space and of course one-fourth less pressure; and at the ninth inch, the

Fig. 118.



end of the stroke, there is, similarly, one-third more space and one-third less pressure.

The whole pressure of steam on the piston, during the last three inches of the stroke, has been obtained without any supply of steam to the cylinder from the steam chest, and constitutes the gain due to using the steam expansively.

It must be borne in mind that, when the piston commenced its seventh inch of stroke and first inch of expansion, the pressure of steam upon it was 50 pounds, and that not until it had reached its seventh inch of stroke and completed its first inch under expansion, had the pressure fallen to 42.86, so that 42.86 is less than the average pressure the piston received during that inch of its stroke, but is as near as we can arrive at it, unless we take the

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movements of the piston and pressures of steam at a greater number of points, as, for instance, at every half inch of piston movement.

It would appear that this saving of steam had been obtained at some sacrifice of the power of the engine, since the piston performed the last 3 inches of its stroke under a reduced pressure of steam; but such is not the case, for if the valve has no steam lap on it, and the steam does not, therefore, work expansively, the exhaust port is not sufficiently open when the piston is at the end of the stroke to permit the steam to escape freely; hence it puts a back pressure on the piston, which is a greater loss to the engine than is caused by the reduced pressure due to working expansively: so that an engine whose valve has no lap will not only use less steam, but will become more powerful if lap be added to the valve.

An experiment made two years ago by the author clearly demonstrated this fact. A new engine, fitted with a common slide valve which had no lap upon it, was attached directly to a pump, which drew water 4 feet and forced it through a 1¼ inch nozzle, a pressure gauge being attached to the air chamber of the pump. Steam at 60 pounds to the square inch was supplied to the engine, whose performance then was to maintain an even pressure of 17 pounds per inch in the air chamber, the engine making 120 revolutions per minute. After running a few days, the slide valve of the engine was taken out and $\frac{5}{16}$ of steam lap was added on each side, a new and larger eccentric being fitted to the engine in order to give the slide valve the necessary increase of stroke. No other part of the engine or pump was altered or removed; but upon turning on the steam, the engine ran up to 175 revolutions, and maintained an even pressure in the air chamber of 34 pounds to the inch.

In the experiment referred to the valve had (in the first instance, when it had no lap) $\frac{1}{16}$ inch of lead, so as to give

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that amount of exhaust opening when the piston was at the end of the stroke. In the second instance, however, when the valve had $\frac{5}{16}$ of steam lap added to it, it was set so as to have not more than $\frac{1}{64}$ of lead, the author being convinced that, when a valve has sufficient lap to give a moderately free exhaust, there is more to be lost by back pressure from excessive lead than to be gained by the small amount of assistance it lends towards making the exhaust more free. If a valve has no lap at all, it may with advantage be given an amount of lead that would otherwise be decidedly detrimental. It would appear, from the amount of lead given to a valve in the early days of steam-engineering, that one of the advantages due to adding lap to the valve (a free exhaust) was largely attributed to the lead of the valve.

Referring again to the advantage in economy due to using (or, as it is commonly called, working) the steam expansively, it is self-evident that, if we have steam at a gauge pressure of 50 pounds per inch (that is, above the pressure of the atmosphere), and permit its escape at any pressure above that of the atmosphere, we shall not have extracted from it all the power it contains, because it may be used at the initial pressure of 50 pounds per inch during a certain portion of the stroke, and, by then being permitted to expand itself before being exhausted, may be employed to perform duty as steam of 49, 48, 47, etc., pounds per inch, and so on down to that point at which the indicating needle or hand of the steam gauge will stand at zero, denoting that there is no longer any pressure in the steam. This last, however, is not actually the case, since the pressures marked on the gauge are in each case 15 pounds per inch less than the actual pressure of the steam when the needle stands at that point, which 15 pounds serves in a high pressure engine to overcome the atmospheric pressure, which, in consequence of the exhaust port being open to the atmosphere, acts upon the exhaust side

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of the piston as back pressure, and therefore has to be overcome by an equal pressure of steam on the opposite side of the piston; so that, when a high pressure engine uses its steam expansively, so that it exhausts at the gauge pressure of zero, it has extracted from the steam all the useful effect possible in such an engine, but at the same time not all the useful effect or power which the steam contains, as will be hereafter explained. This leads us naturally to another consideration, which is that if steam be used expansively in a high pressure engine to an excessive extent, the result is an actual loss of power, because, if the steam on the one side of the piston is at a pressure less than the atmospheric pressure on the other, the latter acts of course as a retarding force to the advancing piston.

The steam passages between the valve seat and the cylinder bore, and the clearance between the piston (when it is at the end of its stroke) and the cylinder cover, are spaces which have each to be filled, during each revolution of the engine, with live steam; and if the engine is not worked expansively, this live steam escapes without giving any of its power to the engine, and is lost, except in so far as it was necessary to fill those spaces. If, however, the engine is worked expansively, the expansive force of such live steam is extracted from it and applied with useful effect upon the piston, the result being an appreciable gain in the economy of steam, especially in those engines which, by reason of having the valve seat in the centre of the cylinder, have very long steam passages, not merely because of the length of such passages, but also because in such cases the steam port serves alternately as the exhaust port, and has therefore to be made of larger proportions than it would need to be if employed as a steam port only, since an exhaust port always requires to have a larger area than a steam port. Hence the content of such passages, together with the clearance before referred to, bears a large proportion to the whole contents of the cylinder; and to extract

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power from the steam contained in them, by utilizing its expansive force, is a considerable gain to the engine.

An approximate calculation as to what extent the steam in a cylinder is working expansively, and its pressure at the termination of each inch of piston stroke, may be made by making the whole distance the piston has moved (under both live and expansive steam) the denominator, and the distance it has moved under expansive steam the numerator of a fraction, and then multiplying the initial pressure by the numerator and dividing by the denominator of the fraction; then subtract the quotient from the initial pressure, the last product being the pressure of the steam. Thus: Supposing the initial pressure of the steam admitted to a cylinder to be 60 pounds per square inch, the length of the piston stroke to be 20 inches, and the supply of steam to the cylinder to be cut off by the valve when the piston has travelled 5 inches of its stroke, what pressure of steam will there be in the cylinder when the piston is at the end of the tenth and twentieth inches of its stroke, respectively (making no allowance for the steam in the passages): Here the tenth inch of stroke—the whole distance moved by the piston $= 10$, distance moved by the piston under expansive steam $= 5$, hence the fraction $\frac{5}{10}$; then the initial pressure $60 \times 5 = 300 \div 10 = 30$; then $60 - 30 = 30 =$ the pounds pressure on the piston when it had arrived at the end of the tenth inch of its stroke.

Again: Whole distance moved by piston $= 20$ inches, distance moved by the piston under expansive steam 15 inches, hence the fraction $\frac{15}{20}$; then the initial pressure of the steam $60 \times 15 = 900 \div 20 = 45$; then initial pressure $60 - 45 = 15 =$ the pressure of the steam in pounds per inch at the end of the twentieth inch of the stroke or piston movement.

By making such a calculation for every inch of the piston movement and setting the figures in a column and adding them together, and dividing their sum total by the

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number of inches in the stroke, we arrive at a rough estimate of the average pressure of the steam upon the piston throughout the stroke.

A review of the above calculations discloses that, as before stated, the pressure of the steam has decreased in precise ratio to the increase of the space it occupied, that is to say, when the piston was at the end of its fifth inch of stroke (the steam supply being cut off), there was five inches of the length of the cylinder filled with steam at a pressure of 60 lbs. per inch; and when the piston was at the tenth inch of its stroke and the steam had expanded so as to occupy ten inches of the length of the cylinder, the pressure was reduced to 30 lbs. per inch; and the same rule applies to the twentieth inch of stroke, for the steam then occupied four times the space it did as live steam, and had therefore fallen to one-fourth of its original or initial pressure. It is to be noted, however, that while such a calculation is absolutely correct as applied to any one definite point of the stroke (making no allowance for the steam in passages and clearance), it is not entirely correct in its results if we take a number of such points to obtain therefrom the actual average pressure of steam throughout the stroke, for the following reason: Suppose we calculate (by the given rule) the pressure of the steam per inch upon the piston when it had concluded its sixth inch of stroke. Here the whole distance moved by piston=6 inches, distance moved under expansion=1 inch, therefore the fraction is $\frac{1}{6}$; then the initial pressure $= 60 \times 1 = 60 \div 6 = 10$, then again initial pressure $60 - 10 = 50 =$ pressure of steam per inch upon the piston at the termination of its sixth inch of stroke. Now while 50 lbs. per inch accurately represents the pressure of steam upon the piston at the termination of its sixth inch of movement, it in nowise represents the average pressure of steam per inch during the whole inch of movement, because the piston commenced that inch of its movement or stroke under 60 lbs. pressure of steam per

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inch, and not until it had concluded that inch of movement was the pressure reduced to 50 lbs. per inch. Nor will it avail us to take the mean between the two, that is, 55 lbs. per inch, as the average pressure for that inch of movement; because, so long as we calculate the pressure at every inch of the stroke, we shall have the same discrepancy between the pressure at the beginning and at the end of the inch of movement, whether it be at the fifth, sixth, or seventh inch, or at 5½, 6½, or 7½ inches of the stroke. To get a more nearly correct result, we must take a greater number of points in the stroke, such as every half or quarter inch of the piston movement; the more points taken, the more nearly correct will be the result obtained. It is, however, generally considered as sufficiently correct for practical purposes to take as many points as there are inches in the piston stroke.

With a common slide valve, it is not practicable to cut off the steam supply to the cylinder sufficiently early in the stroke to effect so large a degree of expansion; because, in the first place, it would require the valve to have an excessive amount of steam lap, and the exhaust would be choked at the cylinder exhaust port, and would take place too early in the stroke, thus causing the piston to travel a large proportion of the latter part of the stroke without having any pressure of steam behind it; and because in the second place, when there is the large amount of steam lap on the valve necessary to cut off earlier in the stroke than at two-thirds (that is, carrying full steam two-thirds of the stroke), the admission, expansion, and exhaust of the steam to, in, and from the cylinder becomes very irregular in the forward as compared to the backward stroke of the engine, which irregularity will be shown and treated upon in connection with the piston movement, steam supply, etc. To obviate the defect (above referred to) of a too early exhaust, the valve may have lap added to its exhaust side, that is to say, the exhaust port of the valve may be made

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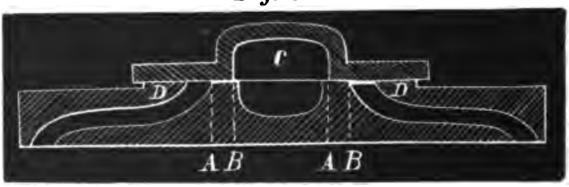
narrower than the width between the two nearest together edges of the steam ports of the cylinder face, as shown in Fig. 119, C being the exhaust port of the valve and from A to B being the lap on the exhaust side. Such lap is, however, only possible when there is a good deal of lap on the steam side of the valve.

If the engine is a fast-running one, and the valve cuts off earlier in the stroke than at three-quarters, the gain secured by the increased retention of the steam, by reason of exhaust lap, is more than counterbalanced by the loss due to its choking the exhaust. A small amount of exhaust lap may be employed instead of giving the valve lead.

A slide valve is sometimes given what is called clearance, that is to say, it is made wider in its exhaust port

Fig. 119.



than are the two nearest together edges of the steam ports, so that (referring to Fig. 119) the port C of the valve would overlap the steam ports to the amount of the clearance, giving to them both an open communication with the port C, and therefore with each other during the instant of time at which the valve is in the centre of its travel. Clearance on the exhaust side is therefore the very opposite of lap on the exhaust side of the valve. The object of clearance is to give the valve a more free exhaust, and it is therefore only resorted to in cases where, the valve having little or no steam lap, the exhaust steam cannot freely escape.

The objection to a valve having clearance is the open communication permitted between the steam and exhaust

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ports, which, though it exists for only a comparatively insignificant space of time, is a radical defect, especially when it is borne in mind that, as we have already shown, a slide valve should always have steam lap, and therefore will always have a proportionate amount of exhaust opening, in addition to that given to it by the lead of the valve. Clearance, then, is an expedient which should never be resorted to, it being a blunder applied merely to remedy a blunder. Clearance to a valve having much lap on its steam-side is altogether inadmissible, since it is not requisite to give a more free exhaust, while it assists in letting the exhaust steam escape earlier in the stroke; and by this means it adds to a defect inherent in slide valves having much steam lap, which is a too early exhaust.

Common slide valves, however, work to better advantage when the lap is so proportioned as to cut off the steam at about three-quarters of the stroke than at any other point, because of the comparatively long stroke of the valve (and hence large eccentric) necessary when much steam lap is brought into requisition, and because of the large amount of friction between the valve and cylinder faces in consequence of the pressure of the steam on the back of the valve. There are of course many devices for balancing such valves and some for reducing the pressure to a minimum, but none have as yet appeared whose benefits have proved such as to cause their general adoption for locomotives or small stationary engines, to which the application of the common slide valve is now almost universally confined.

To reduce the friction to a minimum, that part of the cylinder face upon which the face of the slide valve works may be raised above the general face upon which the steam chest beds, as is shown in Fig. 119, so that the steam lap of the valve may have the steam on the under as well as the outer side, and be to that extent relieved of the outer pressure. In such case, the width of the projecting faces

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(marked D in Fig. 119) should not be any wider than is the bridge (of the cylinder face) between the steam and exhaust ports; otherwise the wear of the face of the bridge will be the greatest and the valve seat of the cylinder face will wear hollow, the valve springing (to fit such face) from the steam pressure on its back. Especially is this the case where a high pressure of steam is employed. It is not uncommon to cut away these faces, leaving them full only around the edges of the ports, which cutting is performed by a slotting drill.

It is advantageous to make the steam ports long and narrow rather than short and wide, so that, when the valve commences to open, whether it be on the steam or exhaust side, a small amount of opening will present a comparatively large area for the ingress or egress, as the case may be, of the steam; hence the supply and exhaust of the steam to the cylinder will be larger in proportion to the valve movement, and therefore more instantaneous. A long port will of course entail a broader valve surface, and hence increased pressure of the valve to its seat; but this is compensated for by the decrease in the stroke of the valve (and hence in the diameter and stroke of the eccentric) permissible with the long port.

The rule sometimes given by which to calculate the required area of a steam port is, say, for a fast-running engine: One-eighth the area of the piston is the proper area of the steam port; the employment of such a rule, however, gives a result bearing no definite relation to the piston speed, and leaves a wide margin of difference, since either 300 or 600 feet of piston travel per minute is a fast-running engine; whereas the amount of steam required to pass through the port for the one speed (supposing both pistons to be of equal diameter) is double that required for the other; while if the port area is larger than necessary, it causes a serious loss of steam; whereas, if it is too small, it wiredraws the steam and fails to supply steam at full

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pressure to the cylinder. The following rule, given by Mr. Bourne, appears to meet the exigencies of the case, by giving the port an area proportionate to the quantity of steam required to pass through it. The rule is: Multiply the area of the cylinder in square inches by the speed of the piston in feet per minute; and divide the product by 4000; the quotient is the area of each steam port in square inches.

MOVEMENTS OF PISTON AND CRANK.

The variation in the supply of steam, when considered in proportion to the amount of piston movement, to which reference has already been made, arises from the irregularity of speed in feet per minute at which the piston travels at different parts of the stroke: which irregularity is due to the varying angles of the connecting and slide-valve rods during the stroke, but mainly to those of the connecting rod. The amount of this irregularity will vary with the length of the connecting rod; the longer the connecting rod is, the less will be its variation.

The fly-wheel, acting as an equalizer of the power of the engine throughout the stroke, travels at a comparatively uniform speed; and nearly the whole of the variation of speed (caused by the unequal admission of steam during one stroke, as compared to the other stroke, necessary to complete a revolution of the engine) falls upon the piston. In an engine of 12 inches stroke, the connecting rod being,

Fig. 120.

say, 23 inches from centre to centre of its journals, the piston will have moved 6¾ inches of its stroke when the crank has performed the first quarter of its revolution, and

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stands at or near its point of full power, as shown in Fig. 120, which represents a cylinder, piston, piston-rod, connecting-rod, and crank in the position referred to, the piston having moved from the end A of the cylinder. While the crank is moving the next quarter of its revolution, the piston will move $5\frac{1}{4}$ inches only, thus completing its stroke of 12 inches. Moving the crank the third quarter of its revolution, we find the piston to have moved back $5\frac{1}{4}$ inches, standing in the same position as it did at the end of its first movement of a quarter revolution. During the last quarter revolution of the crank, the piston moves $6\frac{3}{4}$ inches, both piston and crank returning to the respective positions from which they started.

STEAM SUPPLY.

The inequality of the comparative piston and crank movements here disclosed causes the supply, expansion, and exhaust of the steam (in common or simple slide valve engines) to be irregular and unequal at one end of the cylinder as compared to the other, as shown by the following example, taken from a working engine of 12 inches stroke, the eccentric and connecting rods being each $23\frac{5}{8}$ inches long, the steam ports $\frac{7}{8}$ inch wide, the width between the steam ports being 3 inches and the valve having $\frac{3}{8}$ steam lap, with neither lap nor clearance on the exhaust side. The stroke of the valve was $2\frac{1}{2}$ inches, or just sufficient to permit the steam ports to open to their full extent. Commencing, then, when the piston is at the front end of the cylinder, that is to say, at the end farthest from the crank, we find the following respective movements:

TABLE NO. 1.—FRONT STROKE.

Piston moved inches.	Port open inch.
1	$\frac{9}{16}$
2	$\frac{3}{4}$ barely.
3	$\frac{13}{16}$

Piston moved inches.		Port open inch.
4		$\frac{7}{8}$
5		$\frac{7}{8}$
6		$\frac{7}{8}$ barely.
7		$\frac{3}{4}$
8		$\frac{11}{16}$
9		$\frac{9}{16}$
10		$\frac{3}{8}$
11		$\frac{1}{8}$
$11\frac{1}{8}$	closed, and expansion	begins.
$11\frac{3}{4}$	" " "	ends.
12	exhaust open $\frac{1}{8}$ inch.	

TABLE NO. 2.—THE RETURN ON BACK STROKE.

Piston moved inches.		Port open inch.
1		$\frac{11}{16}$ full.
2		$\frac{7}{8}$
3		$\frac{7}{8}$
4		$\frac{7}{8}$
5		$\frac{7}{8}$
6		$\frac{13}{16}$ full.
7		$\frac{3}{4}$
8		$\frac{5}{8}$
9		$\frac{7}{16}$
10		$\frac{3}{16}$ full.
$10\frac{7}{8}$	closed, and expansion	begins.
$11\frac{1}{4}$	" " "	ends.
12	exhaust open $\frac{1}{8}$ inch.	

It will be at once observed that the supply of steam to the piston is much greater, from the very first inch of piston movement, in the back stroke as compared with that of the front stroke; but this inequality is somewhat compensated for by the fact that the cubic contents of the steam space in the cylinder is greater in the case of the stroke tabulated in No. 1 than it is in No. 2, because of the space occupied during the latter by the piston-rod.

The expansion commences earlier in the stroke, and ends earlier; and the distance moved by the piston under ex-

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pansive steam is $\frac{1}{8}$ inch more in the back than in the front stroke. The effect of the irregularity will, however, be more correctly understood by comparing the movements, as shown in the following table:

TABLE NO. 3.

Movement of crank.	Movement of piston.	Average port opening.
1st quarter	$6\frac{3}{4}$ inches	$\frac{125}{160}$
2d "	$5\frac{1}{4}$ "	$\frac{86}{160}$
3d "	$5\frac{1}{4}$ "	$\frac{134}{160}$
4th "	$6\frac{3}{4}$ "	$\frac{64}{160}$

A comparison of the first and third quarter revolutions of the crank, during each of which it moved from a dead centre into about full power, and during each of which the piston moved from one end towards the middle of the cylinder, shows that, while the piston moved the greatest distance in the first, it received the least amount of average port opening, and hence the least supply of steam. A comparison of the second and fourth quarter revolutions of the crank, during each of which the piston moved from near the middle of the cylinder towards one end, discloses that, while the piston travelled the least distance in the second, it received the most steam during the fourth quarter revolution. Now let us compare the second and third quarter movements of the crank with the piston movement and steam supply. During each of these movements the piston travelled an equal distance; but we find the average opening of port for the admission of steam to be $\frac{5}{16}$ of an inch (nearly one-third) greater in one case than in the other. So likewise a comparison of the first and fourth quarter revolutions of the crank shows that, while the piston and crank moved an equal distance in both cases (namely, the crank a quarter revolution and the piston $6\frac{3}{4}$ inches of the stroke), the average port opening for the supply of steam was very nearly double in the first quarter of what it was in the fourth. So far, then, as we have considered these movements, the

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steam supply has been (in consequence of the area of the port opening) in each case the least, in proportion to the distance moved by the piston, where it should have been the most, and *vice versa.*

The first quarter movement, considered in relation to the second, shows the steam supply to be the greatest when the piston movement is the greatest; but the third quarter movement, as compared with the fourth, discloses the greatest discrepancy of all, since not only was the port opening more than double in one case of what it was in the other, but the greatest amount of port opening was given to the least amount of piston movement.

Considering the port opening with reference to the crank movement only, it would seem to be desirable to have an equal average of opening for each quarter movement; but when considered with reference to the piston movement (that is, with reference to the amount of steam which is required to pass through the port in a given time) it becomes self-evident that the area of the port should be greater when the piston is travelling rapidly than when it is travelling slowly.

We must, however, consider that, during the second and fourth quarter revolutions, the piston is at that end of its stroke where the exhaust takes place; so that the piston is not under steam (during each respective quarter movement) for the whole of the movement. Hence the smallness of the opening of the steam port is not so disproportionate (considering each quarter movement of itself, and not comparatively with another) as it would at first sight appear to be.

It must also be remembered that, since the ports are of rather larger area than they would be if employed as steam ports only, instead of as steam and exhaust ports alternately, the inequality of port area during the movement, shown in the above tables, is not experienced to so serious an extent as it otherwise would be. It is, however, felt by the engine

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TABLE NO. 6.—FRONT STROKE.

Piston moved inches.	Port open inch.	Piston moved inches.	Port open inch.
1	$\frac{5}{8}$	8	$\frac{3}{4}$ full.
2	$\frac{13}{16}$	9	$\frac{5}{8}$
3	$\frac{7}{8}$	10	$\frac{7}{16}$
4	$\frac{7}{8}$	11	$\frac{1}{8}$
5	$\frac{7}{8}$	$11\frac{1}{4}$ closed, and expansion begins.	
6	$\frac{7}{8}$	$11\frac{13}{16}$ expansion ends.	
7	$\frac{7}{8}$	12 exhaust open $\frac{1}{2}$ inch.	

TABLE NO. 7.—BACK STROKE.

Piston moved inches.	Port open inch.	Piston moved inches.	Port open inch.
1	$\frac{13}{16}$	8	$\frac{3}{4}$
2	$\frac{7}{8}$	9	$\frac{1}{2}$
3	$\frac{7}{8}$	10	$\frac{1}{4}$
4	$\frac{7}{8}$	$10\frac{7}{8}$ closed, and expansion begins.	
5	$\frac{7}{8}$	$11\frac{3}{4}$ expansion ends.	
6	$\frac{7}{8}$	12 exhaust open $\frac{3}{8}$ inch.	
7	$\frac{7}{8}$ bare.		

Adding up the area of port opening at each inch of piston movement, and dividing the sum total by the number of inches in the stroke, which will give us in each case the average port area for the whole stroke, we shall find the average for the front end of the lesser valve travel to be $\frac{5}{8}$ of an inch, and for the same end of the greater travel to be $\frac{3}{4}$ of an inch, the average for the back stroke of the lesser travel to be $\frac{94}{160}$, and for the greater to be $\frac{5}{8}$.

A glance at the respective tables will also show the admission of steam to be much greater during the early part of the stroke, in the case of the increased valve travel, which is of great advantage. The quarter movements under the increased valve travel will be:

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TABLE NO. 8.

Movement of crank.	Piston movement.	Average port opening.
1st quarter	$6\frac{3}{4}$ inches	$\frac{138}{160}$
2d "	$5\frac{1}{4}$ "	$\frac{9}{16}$
3d "	$5\frac{1}{4}$ "	$\frac{134}{160}$
4th "	$6\frac{3}{4}$ "	$\frac{87}{160}$

From the above table we find that the increase of valve travel has been more serviceable to the fourth quarter movement than any other, leaving its opening still less than the other, it is true, but still largely increased: which is very important, because it is so much more proportionate to quarter movement No. 2, during which the piston is (as in movement No. 4) moving from full power to a dead centre, and further because it is especially desirable that the average area of the port opening should be as large as possible for and during the quarters having the longest piston movement. We also find that the average port opening for quarter movement No. 3 has not been affected by the increase of valve travel; this again is decidedly beneficial, for it was, under the short valve travel, the greatest of all independent of its proportion to the piston movement, and the most disproportionate of all when considered in relation to the piston movement; but, under the increased valve travel, it is not only not the greatest, but it is less (as is also its piston movement) than is the average port opening of quarter movement No. 1, the crank (during each quarter movement) having moved from a dead centre into full power. These considerations convince us that not only has the increase of valve travel given us a better steam supply, but it has given us one more regular and proportionate to the piston and crank movements.

Now let us examine to what extent and in what way our increase of valve travel has influenced the ports as exhaust ports. Commencing, then, with the front stroke,

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that is, the port at the front end of the cylinder, which exhausts the steam admitted through the area treated of in table No. 1, we find as follows:

TABLE NO. 9.—FRONT STROKE EXHAUST.

Piston moved inches.	Exhaust port opened inch.
$11\frac{7}{8}$	$\frac{1}{16}$
12	$\frac{3}{8}$
Piston returned.	
$\frac{1}{4}$	$\frac{11}{16}$
$\frac{1}{2}$	full.
$9\frac{1}{4}$	full.
$9\frac{3}{4}$	$\frac{3}{4}$
10	$\frac{5}{8}$
11	$\frac{5}{16}$
$11\frac{13}{16}$	exhaust port closed.
12	port again taking steam.

TABLE NO. 10.—BACK STROKE EXHAUST.

Piston moved inches.	Exhaust port opened inch.
$11\frac{7}{8}$	$\frac{1}{8}$
12	$\frac{3}{8}$
Piston returned.	
$\frac{1}{4}$	$\frac{11}{16}$
$\frac{9}{16}$	full.
$9\frac{7}{8}$	full.
$10\frac{1}{2}$	$\frac{11}{16}$
11	$\frac{1}{2}$
$11\frac{1}{2}$	$\frac{1}{4}$
$11\frac{13}{16}$	exhaust port closed.
12	port again taking steam.

Comparing the exhaust opening for the front stroke of both valve travels, we see that the increased travel has given us as free an exhaust in the early part of the exhaust, kept the exhaust port full open during one more inch of piston travel, given us a much more free exhaust

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during the latter part, and finally increased the average of exhaust opening from $\frac{5}{8}$ to $\frac{114}{160}$. Comparing the exhaust opening for the back stroke of both valve travels, we find also that the greater travel has given us a greater exhaust opening in the early part of the exhaust, has kept the exhaust port full open during about $1\frac{1}{4}$ inches more of piston movement, and increased the average of exhaust opening from $\frac{108}{160}$ (which it was under the lesser valve travel) to $\frac{112}{160}$ under the increased travel. Hence our increased travel has been highly advantageous to the opening and keeping open of the ports, both as steam ports and as exhaust ports.

It is here proper to explain how it occurs that the increase of valve travel gives a greater proportionate increase of steam port opening for the early part of the front stroke than it does for the early part of the back stroke, and also a greater proportionate exhaust area during the latter part of the back stroke than during the latter part of the front stroke, the reason for which is that the increase in the travel of the valve (and hence in the throw of the eccentric) increases the lead of the valve; and the altering of the position of the eccentric to take away this increase of lead brings the eccentric into such a position that a line drawn from the centre of its bore to the most distant part of its circumference, representing the throw of the eccentric, would be nearly true (if it were circular instead of straight) with the circumference of a circle described from the centre of the bolt at the opposite end of the eccentric rod, as shown in Fig. 121, A being the joint of the slide valve spindle and eccentric rod end, B the line representing the throw of the eccentric and showing the position in which the eccentric requires to be set in the case of the lesser valve travel, C a line representing the throw line of the eccentric as it is when the eccentric is made to suit the increased valve travel, and the dotted line D a circle struck from the centre of A.

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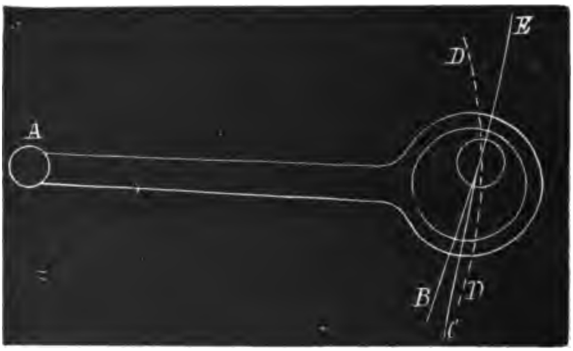
It is apparent that the nearer the line representing the throw of the eccentric (that is, the line B in Fig. 121) approaches in its main course to a line struck from the centre of the eccentric rod end (D D in Fig. 121), the less effect will an increase or decrease in the throw of the eccentric have in altering the position of the slide valve spindle (and hence of the valve) either backward or forward, at the time when the eccentric is in the position shown in Fig. 121. And, as the greater the increase in the throw of the eccentric the nearer will the throw line of the eccentric, when the latter is set, approach the line D D, it follows that the less will the difference in the position of the spindle and rod joint (and hence of the valve) be when the

Fig. 121.



eccentric is in the particular position shown. When, however, the crank has made one-half of a revolution, and the throw line of the eccentric stands in the position denoted by the line E in Fig. 121, the least alteration in the length of the throw of the eccentric will have a great effect in altering the position of the joint A, and hence of the slide valve, the effect being to bring the joint A nearer to the crank shaft in proportion to the increase, and to throw it

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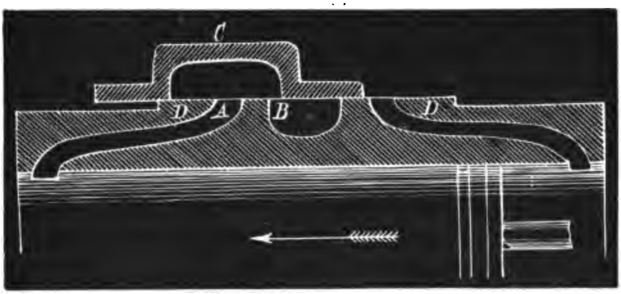
farther back from the crank shaft in proportion to any decrease in the throw of the eccentric; which shows why an increase in the throw of the eccentric (or, in other words, of the travel of the valve) makes the difference in the port opening before referred to.

MOVEMENT OF THE PISTON AND THE CRANK.

Let us now place upon the valve a maximum of steam lap, and we shall find an entirely new element under consideration. It is that, although steam lap to a certain amount gives us a more free exhaust, beyond that amount it cramps the exhaust by closing the exhaust port of the cylinder. Suppose, for instance, we give the valve, of the engine upon which we have been experimenting, seven-eighths of steam lap (instead of three-eighths, as formerly). We shall find that, at one part of the stroke, the valve, after having opened the exhaust port full, will commence to close the cylinder exhaust port, so that, while the steam port (being used as an exhaust port) is full open, the exhaust port of the cylinder is as shown in Fig. 122, A being

Fig. 122.



the steam port operating as an exhaust port and full open; whereas the exhaust port B of the cylinder is closed to such a degree as to cramp the exhaust to the extent of the

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difference in width of opening between the ports A and B. We have, however, already decided that the exhaust opening should never be less (during any part of the exhaust) than one-half the full width of the steam port; hence it follows that the maximum of steam lap should in all cases be such an amount as will leave an exhaust opening, at all times, at both the ports A and B, Fig. 122, equal to one-half of the full width of the port A; and it also follows that the limit to which a valve may be made to work expansively is defined or governed by the width of opening which it will leave at B.

We will now place the engine upon which we have experimented under conditions to work to a maximum of expansion, giving to the valve seven-eighths inch of steam lap on each side, by increasing the valve travel to three and nine-sixteenths inches, and lengthening the eccentric rod one-eighth inch (which will be necessary for the increased travel).

Having effected these alterations and moved the engine round a revolution, the first thing to attract our attention is that the front steam port is not left full open by the valve at any part of the stroke, making it appear that the eccentric rod is either too long or that the valve is not properly set; that neither of these defects exists is proved by the fact that the valve lead is equal at each end of the stroke while our valve travel is sufficient to fully open both ports (provided the valve movement were regular); for the width of the steam port, seven-eighths, added to the steam lap, seven-eighths, amounts to one and three-fourths inches, which, multiplied by two, is three and a half; whereas, our travel is three and nine-sixteenths inches, or one-sixteenth more than would appear to be actually necessary. The valve travels over and beyond the back port to the amount of the deficiency of the opening of the front port added to the one-sixteenth inch of increase of travel,

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and this irregularity of movement is irremediable in all valves having a maximum of steam lap; so that, if the lead be made equal at each end of the stroke, the front port never opens (as a steam port) to its full width. The irregularity is not, however, a very serious defect, since it does not affect the port unfavorably as an exhaust port, and since the port is, of itself, wider than it would require to be if used as a steam port only, and is, therefore, open sufficiently for the admission of the steam. It will naturally occur to the mind that this defect could be remedied by increasing the valve travel; but were recourse had to this expedient, it would cause the valve, when in the position shown in Fig. 122, to leave the opening at B still less; and we must, therefore, leave the valve travel as it is, bearing in mind that an increase of valve travel, while advantageous, as we have already shown, to a valve having a small amount of steam lap, is inadmissible, except it be to a very small degree, in one having a maximum of such lap.

The causes which effect partial closure of the front port are those set forth in Fig. 121 and its accompanying explanation. We have given the valve three-fourths of an inch more travel than it had in our former experiment; and the effects of this increase are experienced more in one part of the valve travel than in another, as already explained. We have also increased the lap of the valve, and have had, as a natural consequence, to increase the lead of the eccentric so as to get the same amount of lead on the valve as we had in our previous experiment (that is, one sixty-fourth of an inch); for an increase in the amount of the steam lap on a valve necessitates an increased amount of lead of the eccentric (to get an equal amount of lead on the valve) and therefore a greater irregularity in the movement of the valve. The lead of an eccentric (which gives us the lead of the valve) is the amount to which it is set

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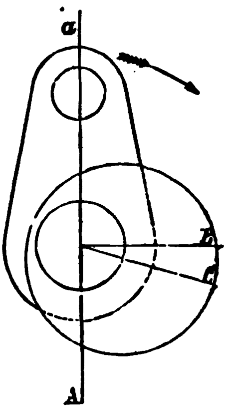
so that its throw line stands in advance (in the direction in which the engine is to run) of a line at right angles to the centre line of the crank, as shown in Fig. 123, A A being the centre of the line crank; B a line at right angles to A A; C the throw line of the eccentric; and the distance from C to B, at the periphery of the eccentric, the lead of the eccentric, the arrow denoting the direction in which the engine is to run.

Fig. 123.



In a former experiment, we found that increasing the throw of the eccentric, and hence the travel of the valve, rendered it necessary to diminish the lead of the eccentric, and therefore tended to diminish the irregularity of the valve movement. The reason, in that case, was that no addition had been made to the steam lap of the valve; for if such an addition had been made, the eccentric would have required to have been given increased instead of diminished lead, as shown in Fig. 121.

Proceeding with our maximum increase of steam lap, we find the movements to be as follows:

TABLE NO. 11.—FRONT END.

Piston moved inches.	Port open inch.	Piston moved inches.	Port open inch.
1	$\frac{5}{8}$	7	$\frac{1}{2}$
2	$\frac{3}{4}$	8	$\frac{5}{16}$
3	$\frac{13}{16}$	$9\frac{1}{4}$ closed, and expansion begins.	
4	$\frac{13}{16}$	$11\frac{3}{8}$ closed, but expansion ends.	
5	$\frac{3}{4}$ full.	12 exhaust port open full.	
6	$\frac{11}{16}$		

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TABLE NO. 12.—BACK END.

Piston moved inches.	Port open inch.	Piston moved inches.	Port open inch.
1	$\frac{13}{16}$	6	$\frac{5}{8}$
2	$\frac{7}{8}$	7	$\frac{7}{16}$
3	$\frac{7}{8}$	$8\frac{5}{8}$ closed, and expansion begins.	
4	$\frac{7}{8}$	11 closed, but expansion ends.	
5	$\frac{3}{4}$	12 exhaust port open full.	

We find here that the steam in the back end commenced to work expansively three-quarters of an inch earlier in the stroke than that in the front end of the cylinder, and that it was used expansively during two and five-eighths inches of the stroke instead of two and one-eighth, as in the front stroke; and furthermore, that the steam in the back end commenced to exhaust when the piston had moved eleven and one-eighth inches of its stroke, leaving it to travel the other seven-eighths of an inch without any pressure behind it; while the steam in the front end commenced to exhaust when the piston had moved eleven and three-eighths inches of the stroke, leaving it to travel the other five-eighths without any steam pressure behind it.

Such are the irregularities due to the employment of a maximum of steam lap and its accompanying lead of eccentric, the greatest defect of them all being that the exhaust port opens too early in the stroke, and thus the engine loses a large part of the effectiveness of the steam. It is the variation of the exhaust port opening after the piston has commenced its return stroke (which does not, therefore, appear in the previous tables) that prevents us (as before stated) from adding any more steam lap to the valve, as is shown in the following tables of the exhaust openings:

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TABLE NO. 13.—EXHAUST AT THE FRONT END.

Piston moved inches.	Port A, Fig. 122, open inch.	Port B, Fig. 122, open inch.
$11\frac{3}{4}$	$\frac{3}{8}$	$1\frac{3}{4}$
12	$\frac{7}{8}$	$1\frac{3}{8}$
Return stroke		
1	$\frac{7}{8}$	$\frac{5}{8}$
2	$\frac{7}{8}$	$\frac{1}{2}$
3	$\frac{7}{8}$	$\frac{1}{2}$
4	$\frac{7}{8}$	$\frac{9}{16}$
5	$\frac{7}{8}$	$\frac{11}{16}$
6	$\frac{7}{8}$	$\frac{7}{8}$
7	$\frac{7}{8}$	1
8	$\frac{7}{8}$	$1\frac{5}{16}$
9	$\frac{3}{4}$	$1\frac{5}{8}$
10	$\frac{3}{8}$	$1\frac{3}{4}$
11	closed.	

TABLE NO. 14.—EXHAUST AT THE BACK END.

Piston moved inches.	Port A, Fig. 122, open inch.	Port B, Fig. 122, open inch.
$11\frac{3}{4}$	$\frac{7}{16}$	$1\frac{3}{4}$
12	$\frac{7}{8}$	$1\frac{7}{16}$
1	$\frac{7}{8}$	$\frac{7}{8}$ barely.
2	$\frac{7}{8}$	$\frac{11}{16}$
3	$\frac{7}{8}$	$\frac{5}{8}$ full.
4	$\frac{7}{8}$	$\frac{11}{16}$
5	$\frac{7}{8}$	$\frac{3}{4}$
6	$\frac{7}{8}$	$\frac{13}{16}$
7	$\frac{7}{8}$	$\frac{15}{16}$
8	$\frac{7}{8}$	$1\frac{1}{8}$
9	$\frac{7}{8}$	$1\frac{3}{8}$
10	$\frac{5}{8}$	$1\frac{11}{16}$
11	$\frac{3}{16}$ full	$1\frac{3}{4}$
$11\frac{1}{4}$	closed.	

We here find that the exhaust opening, during the early part of the stroke, that is, from the first to the fifth inch of piston movement, was less at B than it was at A, in Fig.

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122, and was, at one part of each stroke, but little more than one-half the full width of A, and therefore as small as is compatible with an exhaust sufficiently free for a fast running engine. We have, in point of fact, by the partial closure of B, filched from the exhaust opening to enable us to use the steam more expansively; and in the case of a very fast running engine, we have rather lost than gained by the operation. In locomotives (the piston travel being very fast) sufficient steam lap is employed to leave the opening at B equal, at all parts of the stroke, to the full width of the steam ports.

It has been already remarked that lap on the exhaust side of the valve is sometimes employed to prevent the steam from exhausting too early in the stroke; and that, whatever the amount of such lap, it cramps to a like amount the exhaust opening. How, then, it will naturally be asked, can exhaust lap be employed at all, since the opening at B is already as small as admissible, and such lap would make it still less? This leads us to the consideration of the width of the exhaust port of the cylinder, that is to say, of the port E, in Fig. 116. We have in all our previous experiments made this port twice the width of the steam port, which is the proportion generally employed; and which proportion is ample, providing that the amount of steam lap is not more than three-quarters that of the width of the steam port; because, up to that amount, the exhaust opening at B, in Fig. 122, will at all parts of the stroke be equal to that at A, in Fig. 122, while beyond that amount it will be, as shown, less than at A.

The width of the cylinder exhaust port may be, if the valve have little or no steam lap, even less than twice the width of the steam port; for instance, the port E, Fig. 116, has been in all our experiments $1\frac{3}{4}$ of an inch wide, the steam ports being $\frac{7}{8}$ of an inch wide; but the valve having no steam lap, the port E may be made $1\frac{1}{4}$ inches wide only, in which case (the bridges and steam ports remaining

unaltered in width) the valve would require to have a narrower exhaust port, and would hence be to that amount narrower in its total width, thus reducing the area of its back face, upon which the steam acts to press it to its seat, and hence reducing the friction upon its face and the power required to move it.

To resume, then, we find that, under a maximum of steam lap, the valve permits, as before stated, the steam to exhaust too early in the stroke, and that, to remedy this defect, we have no alternative but to add lap on the exhaust side of the valve. To do this, however, would reduce the exhaust opening of the cylinder exhaust port; hence some alteration in the proportions of the openings is necessary to enable us to accomplish such an end, which alteration is in making the cylinder exhaust port more than twice the width of the steam port, since exhaust lap can only be usefully employed under such conditions. In order to show the benefits due to exhaust lap, we will again alter our engine, giving the steam side of the valve an additional one-sixteenth of an inch of lap, and placing seven-sixteenths of lap on the exhaust side; hence our next experimental engine will have the following dimensions: Steam ports seven-eighths of an inch wide, ribs (or bridges) each five-eighths of an inch wide, cylinder exhaust port two and one-quarter inches wide, exhaust port of valve two and five-eighths inches wide, steam lap fifteen-sixteenths of an inch, exhaust lap seven-sixteenths, travel of valve three and nine-sixteenths inches, eccentric-rod twenty-three and three-quarters inches long.

The disadvantage arising from these alterations will be that, in consequence of widening the cylinder exhaust port, we have thrown the steam ports wider apart, and have hence had to widen the valve, and, therefore, to increase the area of the back of the valve upon which the steam acts, pressing the valve to its seat; so that we have proportionately increased the friction due to moving the

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valve under its pressure: unless the valve is balanced, in which case the increase of area should apparently make no appreciable difference. The advantage due to balancing slide valves has, however, never been satisfactorily demonstrated, the attempts to introduce them upon locomotives having been almost abandoned. We have, on the other hand, shortened the length of the steam passages to the amount to which we have widened the cylinder exhaust port, and gained several other advantages, as the following tables of movements disclose:

TABLE NO. 15.—FRONT STROKE.

Piston moved inches.	Port open inch.	Piston moved inches.	Port open inch.
1	$\frac{5}{8}$	7	$\frac{7}{16}$
2	$\frac{3}{4}$	8	$\frac{1}{4}$
3	$\frac{3}{4}$	$9\frac{1}{8}$	closed, and expansion begins.
4	$\frac{3}{4}$	$11\frac{3}{4}$	closed, but expansion ends.
5	$\frac{11}{16}$	12	exhaust port open $\frac{9}{16}$ inch.
6	$\frac{5}{8}$ bare		

TABLE NO. 16.—BACK STROKE.

Piston moved inches.	Port open inch.	Piston moved inches.	Port open inch.
1	$\frac{3}{4}$	6	$\frac{7}{16}$
2	$\frac{7}{8}$	7	$\frac{1}{4}$
3	$\frac{7}{8}$	8	closed, and expansion begins.
4	$\frac{3}{4}$	$11\frac{1}{2}$	closed, but expansion ends.
5	$\frac{5}{8}$	12	exhaust port open $\frac{5}{8}$ inch.

In table No. 11, on page 342, we find that the widening of the cylinder exhaust port and the addition of lap on the exhaust side of the valve has retained the steam in the cylinder during three-eighths of an inch more of the piston movement in the front stroke, and during one-half

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of an inch more in the back stroke than was previously the case; and further, that we have used the steam expansively during half an inch more of the front and during seven-eighths of an inch more of the back stroke than in our last engine, the steam supply in the front stroke having been cut off a trifle earlier and the expansive steam retained longer in the cylinder. In the back stroke, however, the steam supply is cut off five-eighths of an inch earlier in the stroke and the expansive steam exhausted half an inch later in the stroke, so that the back stroke has been benefited far more by the alteration, than has the front stroke.

We shall find, however, on examination that the average width of the port opening for the admission of steam has been slightly reduced; this, however, is not of great consequence, since the ports have (as before stated) a larger area than they require when in operation as steam ports; so that, if the exhaust is found to be as free as before, the last alteration of our engine will have been beneficial excepting in that it increases the friction of the valve to its seat.

TABLE NO. 17.—EXHAUST OF STEAM AT FRONT END.

Piston moved inches.	Exhaust A, (Fig. 122), open inch.	Cylinder Exhaust B, (Fig. 122), open inch.
$11\frac{7}{8}$	$\frac{1}{8}$	$1\frac{15}{16}$
12	$\frac{9}{16}$	$1\frac{9}{16}$
Return stroke		
1	$\frac{7}{8}$	$\frac{3}{4}$
2	$\frac{7}{8}$	$\frac{5}{8}$
3	$\frac{7}{8}$	$\frac{5}{8}$
4	$\frac{7}{8}$	$\frac{3}{4}$
5	$\frac{7}{8}$	$\frac{7}{8}$
6	$\frac{7}{8}$	$1\frac{1}{16}$
7	$\frac{7}{8}$	$1\frac{1}{4}$
8	$\frac{5}{8}$	$1\frac{1}{2}$
9	$1\frac{5}{16}$	$1\frac{13}{16}$
$9\frac{3}{4}$	closed, and steam cushions.	

In order to obtain the average exhaust opening during the stroke, we must, of course, at each inch of piston move-

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ment, take the port opening of A or B (as the case may be), which is the smallest; commencing, then, when the piston is at the end of the stroke, a calculation will give us $\frac{11}{16}$ of an inch as the average exhaust opening in our last table, against $\frac{10}{16}$ as the average exhaust shown in table No. 13.

TABLE NO. 18.—EXHAUST OF STEAM IN BACK END.

Piston moved inches.	Exhaust A, Fig. 122, open inch.	Exhaust B, Fig. 122. open inch.
$11\frac{3}{4}$	$\frac{1}{8}$ full	$1\frac{7}{8}$
12	$\frac{5}{8}$ barely	$1\frac{7}{16}$ full.
1	$\frac{7}{8}$	$\frac{7}{8}$
2	$\frac{7}{8}$	$\frac{3}{4}$
3	$\frac{7}{8}$	$\frac{3}{4}$
4	$\frac{7}{8}$	$\frac{3}{4}$
5	$\frac{7}{8}$	$\frac{13}{16}$
6	$\frac{7}{8}$	$\frac{7}{8}$
7	$\frac{7}{8}$	$1\frac{1}{16}$
8	$\frac{13}{16}$	$1\frac{1}{4}$ full.
9	$\frac{1}{2}$	$1\frac{9}{16}$
10	$\frac{3}{16}$	$1\frac{7}{8}$
$10\frac{9}{16}$	closed and steam cushions.	

The average exhaust of the above is $\frac{113}{160}$ of an inch, against the average of $\frac{116}{160}$ of an inch shown in table No. 14, which shows a slight loss in our last experiment; this is, however, an apparent and not a real loss, for the reason that, in our last experiment, the steam was cut off earlier in the stroke, so that the quantity of steam to be exhausted was less than in the former instance; hence the exhaust opening, in our last experiment, when considered with relation to the quantity of steam required to pass through it in a given time, becomes greater than was formerly the case. It will also be observed that the exhaust in our last experiment is (in both strokes) more free during the early part of the stroke, that is to say, from the first to the fifth inch of the piston movement, than was

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the case in our previous experiment, which is a gain of great value, since it is during that part of the stroke that the exhaust opening is at its least, from the partial closure of the cylinder exhaust port.

In the front stroke, at the $9\frac{3}{4}$ inches, and in the back stroke, at the $10\frac{9}{16}$ inches of piston movement, the exhaust is closed, so that whatever steam, on the exhaust side of the piston, remains in the cylinder at those points, is compressed by the advancing piston and acts as a cushion to reverse the motion of the reciprocating parts of the engine easily and without noise (in the same manner as the same end is obtained by giving lead to the valve). It is the lap on the exhaust side of the valve which causes this partial closure and compression of the exhaust steam (which is commonly called cushioning on exhaust lap), and which effects a saving of steam, inasmuch as it may be so proportioned as to enclose and compress sufficient steam to just fill the steam passages with steam at full pressure by the time the piston has arrived at the end of its stroke; so that, when the valve opens, no steam will be required from the steam chest to fill such passages, and the valve need not therefore be given any lead, which, in turn, leads to another advantage, inasmuch as to take the lead off the valve, we must set the eccentric back so that its throw line will be more nearly at a right angle to the centre line of the crank, and the variation in the valve movement (explained in Fig. 120, and its accompanying remarks) will be less. By taking the lead off the eccentric, we however decrease the opening of the steam port during the first two inches of the piston movement, which is a decided disadvantage, even though the average opening of the steam port remains the same in either case, because the closure of the port of the valve is proportionately delayed.

The extreme limit to which the addition of steam lap, the widening of the cylinder exhaust port, and the addition of exhaust lap may be usefully employed, is governed by,

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first, the exhaust opening becoming diminished when the piston is at the end of the stroke and during the latter part of the exhaust; secondly, by the increased pressure of the valve to its seat (already referred to); thirdly, by a proportionate increase in the travel; and fourthly, by the point in the stroke at which the exhaust lap will close the exhaust port, and thus shut in and compress a portion of the steam, on the exhaust side of the piston, in the cylinder; it being evident that, if the quantity of steam so enclosed be excessive, the piston will compress it to such an extent as to make its pressure, by the time the piston has arrived at the end of the stroke, greater than is the pressure of the steam in the steam chest, and of course very much greater than the pressure of the steam on the steam side of the piston (which has decreased in consequence of its expansion), thus entailing a serious back pressure, and causing the steam compressed in the steam passage to be forced back into the steam chest so soon as the valve opens. It is obvious, however, that if the valve has any lead on it, this back pressure will be less than if there were no lead, because the steam would be forced back into the steam chest earlier, and therefore before it was compressed to so great a degree; but in either case sufficient exhaust lap to cause such steam to be forced by the piston back into the steam chest would entail a loss of power from back pressure, and place a severe strain on some of the parts of the engine as already explained in our remarks on excessive lead.

To illustrate these points let us alter our engine as follows: Steam ports seven-eighths of an inch wide, ribs five-eighths of an inch wide, cylinder exhaust port two and three-quarters inches wide, steam lap one and one-eighth inches, exhaust lap three-quarters of an inch.

These alterations necessitate that the valve travel be increased from three and nine-sixteenths inches to four inches, causing an increase in the distance travelled by the valve,

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and, therefore, in the power employed in moving it, of over 12 per cent.

The valve will now be eight instead of seven and one-eighth inches wide as before, causing it to be pressed to its seat with over 12 per cent. more pressure than before. The exhaust opening will be diminished as follows (those points in the stroke here omitted not being affected by the change):

TABLE NO. 19.—EXHAUST AT FRONT END.

Piston moved inches.	Exhaust open inch.	Loss inch.
12	$\frac{1}{2}$	$\frac{1}{16}$
Piston returned		
7	$\frac{5}{8}$	$\frac{1}{4}$
8	$\frac{5}{16}$	$\frac{5}{16}$
9	exhaust closed, cushioning begins.	

TABLE NO. 20.—EXHAUST AT BACK END.

Piston moved inches.	Exhaust open inch.	Loss inch.
12	$\frac{3}{8}$	$\frac{1}{4}$
Piston returned		
7	$\frac{3}{4}$	$\frac{1}{8}$
8	$\frac{9}{16}$	$\frac{1}{4}$
9	$\frac{1}{4}$	$\frac{1}{4}$
$9\frac{7}{8}$	exhaust closed, cushioning begins.	

Here, then, we have a large decrease in the exhaust openings, and have cushioned on exhaust lap three-quarters of an inch earlier in the front stroke and eleven-sixteenths of an inch earlier in the back stroke: the other alterations being that the expansion of our new engine will begin at eight and three-quarters inches of the front and at seven and five-eighths inches of the back stroke, that is to say, the steam has been used expansively during five-eighths of an inch more of the piston movement during the front, and during five-eighths of an inch more of the back stroke than was the case previous to the last alteration made in

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our engine. The effect of such a movement would be to place an amount of back pressure (due to cushioning on the exhaust side to an excessive degree) so great as to force the valve off its seat and produce a serious strain upon the engine, and to produce a back pressure during the earlier part of the exhaust by cramping it.

Exhaust lap, sufficient to prevent the exhaust from taking place too early in the stroke, is shown by our tables to be desirable; but when it is employed to cushion, or, in other words, to answer the purpose of lead, great care must be taken as to its proportion, which must, in all cases, depend upon the pressure of the steam used, and the speed at which the piston travels. With high pressures and speeds, a minimum only of exhaust lap is permissible. Another effect of exhaust lap is to take some of the lead off the eccentric, and to that extent to correct the irregularity in the points of cut-off, expansion, etc.

It will be observed that the variation in the point of cut-off at one end, as compared to the other end of the stroke, becömes greater in proportion to the increase of steam lap; and there is no way of remedying this defect except we produce still greater evils in other directions. Were we to equalize those points of cut-off by giving different amounts of steam and exhaust lap at one, as compared to the other end of the valve, we should increase the variation in the steam and exhaust openings, and cushion at widely differing points in the stroke; so that, when we have proportioned the steam lap to cut-off at about three-quarters of the stroke, and the exhaust lap so as to leave the exhaust port open (when the piston is at the end of the stroke) to the amount of about two-thirds of the full width of the steam port, we have obtained all the benefits due to the employment of either of them, nor can we alter the valve to accomplish a gain in any direction without entailing a loss in another.

If the cylinder exhaust port is twice the width of the

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steam port, and no exhaust lap is employed, the valve may have steam lap to about the width of the steam port; but if the cylinder exhaust port is made more than twice the width of the steam port, a proportionate amount of steam and exhaust lap may be added. For locomotives, common proportions are: steam ports one and one-quarter inches wide, rib one inch, cylinder exhaust port two and one-half inches, steam lap one inch, lead of valve three-sixteenths of an inch, travel of valve four and one-half inches, exhaust lap being dispensed with, except it be sufficient to just prevent communication between the steam ports when the valve is in the middle of its travel.

To Measure the Throw of an Eccentric.—Measure the distance between the bore and the extreme diameter on the heaviest side, and subtract from it the distance between bore and the extreme diameter on the lightest side, and the remainder is the throw of the eccentric, or, what is the same thing, *half* the travel of the valve.

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CHAPTER XIX.

HOW TO SET A SLIDE VALVE.

IN setting a slide valve, we are confronted with the following considerations:

Our object is to cause the admission to expansion of and exhaust from the cylinder of the steam equal for each stroke. This, however, we are unable to attain, because of the angle of the connecting rod. If we set the valve so that the exhaust commences in the same relative position of the piston at one stroke as compared to the other, the valve will not admit the steam to the cylinder in the same relative position of the piston at one end of the stroke as compared to the other—that is to say, the valve being set so that the exhaust will take place when the piston has moved an equal number of inches of the stroke at either end of the cylinder, the steam port, when the crank is on the respective dead centres, will be wider open at one end than at the other. Then, again, if we set the valve so that the exhaust commences at an equal part of the stroke at either end of the cylinder, the exhaust port will be wider open when the crank is on one dead centre than it will when the crank is on the other dead centre. Whereas, if we set the valve so that the steam port at each end is open to an equal amount when the crank is on either respective dead centre, the exhaust port will also be open at each end to an equal amount when the crank is on the dead centre. Thus, by setting the valve so that it has an equal amount of lead at each end of the piston stroke, the exhaust ports will be open to an equal amount when the piston com-

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mences its return stroke at either end of the cylinder. It is always, therefore, preferred to set the valve so that it shall have lead to an equal amount when the crank is on the dead centre.

If the stroke of a valve is made to be twice the width of the steam port added to twice the amount of the lap, it will be found that the steam port at the end of the cylinder farthest from the crank will not open fully, while that nearest to the crank will have the valve travel past it to an equal amount; the degree of this difference becoming greater as the amount of the lap is increased, and hence, as the amount of the lead or angular advance of the eccentric becomes greater.

The exhaust of the steam will, when the lead of the valve is equal at each end of the stroke, take place earlier in the stroke in the front end of the cylinder—that is, the end the farthest from the crank—than it will at the back end, while the steam will work expansively during a greater part of the stroke when it is in the back end than will be the case when it is in the front end of the cylinder. Having noted these facts, we may proceed to set a valve, the first operation being to carefully remove, by blowing or washing out, any filings or scrapings that may have lodged in the ports while operating upon. The valve-seat, or the cylinder, the bore of the cylinder, the valve-face, and the face of its seat, having been carefully cleaned and then oiled, we may connect the various parts, and find and mark the dead centres or dead points of the stroke as follows:

In Fig. 124 A represents the guide-bar, B the guide-block, C the fly-wheel, D the crank, E the eccentric, and F the centre-line of the connecting-rod of an engine intended to run in the direction of the arrow.

Giving the wheel a turn or two in the direction in which it is intended to run, we allow it to come to rest, so that the motion-block B will be at very nearly the end of its

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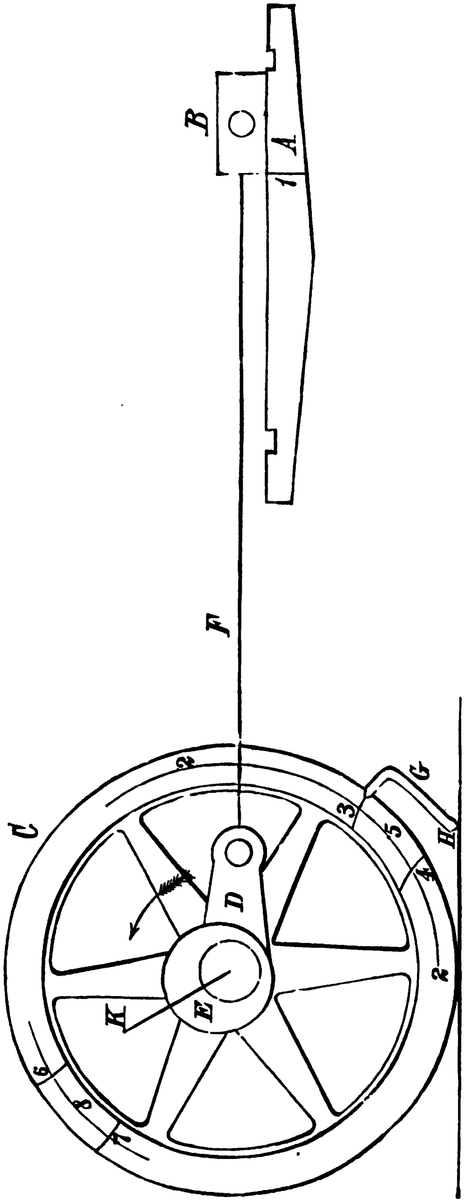

Fig. 124.

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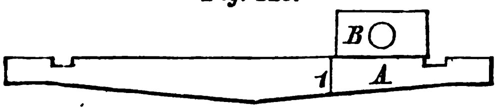
stroke on the guide-bar A, and then placing the edge of a straight edge along the end of the guide-block B, the straight edge at the same time overlapping the face of the guide-bar, we mark on the face of the latter the line 1, which will thus be quite even with the end-face of the guide-block. We then (after chalking it to make the marks show plainly) mark on the face of the wheel the line 2, which should be true with the centre of the main shaft, but which can be marked from the rim of the wheel with a pair of compass calipers, providing that rim has been trued up in the lathe. We next, with a piece of iron wire or rod bent as shown by G, mark at some fixed point, such as shown at H; make a centre-punch mark, and resting one end of the scriber G in the fixed centre-punch mark, we scribe with the other end upon the edge of the wheel the line 3, as shown in the illustration. Our next operation is to move the wheel forward in the direction in which it is to run, so that the crank will move to the dead centre, and the guide-block will leave the line 1, as shown in Fig. 125, and the motion of the wheel being

Fig. 125.



continued, the guide-block will return to the mark 1, the wheel being moved very slowly indeed, so that there will be no trouble so to move it that the end of the guide-block will come to rest exactly fair with line 1. If, by chance, the end of the guide should move past the line, the wheel should be turned well back—that is to say, back to the end of the stroke—and again moved slowly forward till it comes fair with the line 1. The object of this is that the guide-block shall always approach the line moving in the direction in which it will, while performing that stroke, move when the

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engine is at work, so that all the working parts will be brought to a bearing in the direction in which they will bear when at work, and hence any spring or lost motion in any of the parts will not affect the setting of the valve.

Suppose, for instance, there was even a trifling amount of play in the eccentric or any of the bolts, and that the end of the guide-block on its return stroke having moved a trifle past the line 1, we move the wheel backward a trifle to correct the error, thus making the block approach the line from the opposite direction to what it will approach it when at work and travelling on that stroke, then part of the movement of the wheel will have been lost (so far as the movement of the guide-block is concerned), having been expended in taking up the lost motion. It makes no difference if the engine is to run both ways, for in that case we observe the same precaution in moving the wheel, setting the valve in the forward gear, and then trying it in the backward gear, and dividing the difference, if there be any.

To proceed, then, the guide-block having returned even with the line 1, we take our wire scriber, rest one end in the fixed point, and with the other end mark on the edge-face of the wheel line 4, which will then occupy the place that line 3 does in our engraving. Our next duty is to find the centre between lines 3 and 4 as shown in Fig. 126, which

Fig. 126.

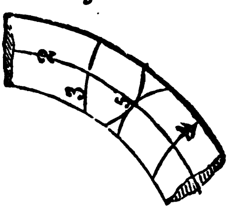
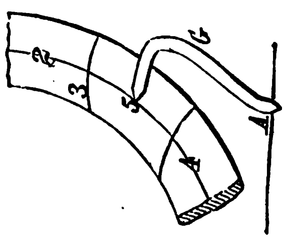


Fig. 127.



we obtain from lines 3 and 4, and which we mark with a

fine centre-punch mark, as shown at 5. And it will readily be perceived that if we move the wheel round so that the scriber G resting in the fixed centre-point as shown in Fig. 127, the end will be true with centre-punch mark 5, the motion-block, and hence the piston and crank, will be exactly on the dead centre at that end of the stroke.

We next move the wheel around, so that the guide-block will be nearly at the end of its stroke at the opposite end of the guide-bar, and mark a line occupying the same relative position at that end as line 1 does at the other end, and repeat the whole previous operation, thus marking new lines corresponding to the lines 2, 3, 4, and 5, but on the opposite diameter of the wheel; thus we shall obtain the lines 6 and 7 in Fig. 124, and from them the centre-punch mark 8, which will serve the same purpose at that end of the stroke as does the centre-punch 5 at the opposite end.

Fig. 128.

Our next procedure is to provide a small wooden wedge, such as is shown in Fig. 128, making one end of a thickness equal to about half the amount of lead it is intended to give the valve, and the other about twice as thick as the intended amount of lead, its length being about three inches. We then move the wheel in the direction in which it is intended to run, until the scriber, one point resting in the fixed centre-punch mark, the other will be exactly even with centre-punch mark 5, and the engine will be on the forward or front dead centre.

We are now ready to set the eccentric, and the question arises, which way the engine ought to run? We have performed all our operations thus far with a view to have the engine run in the direction denoted by the arrow in 124; for had the engine been intended to run in the opposite direction, we should have drawn line 1 while the guide-block was in the same position on the guide-bar, but with the

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crank on the other side of the same dead centre. The direction of arrow C, *Fig.* 129, is the correct one in which an engine should run, if circumstances permit, for the following reasons: in Fig. 129, if we suppose A to represent the centre-line of the connecting-rod, and the engine to be running in the direction of the arrow B, then the strain on the connecting-rod will be in a direction tending to compress it, the strain on the guide-bar being in the direction to force the cross-head guide-blocks down upon the guide-bars, and hence to produce the most friction; whereas if the engine was running in the direction denoted by the arrow C, the strain upon the connecting-rod will be one in a direction to pull it apart, and hence to lift it and the cross-head guide-blocks from the guide-bars, so that the centre line of the connecting-rod would stand in the direction of the line D. When the crank is on the other side of the dead centres, the same effect in either case is produced. Now it is quite true that so long as the guide-blocks fit to the guide-bars, the rod cannot move in any

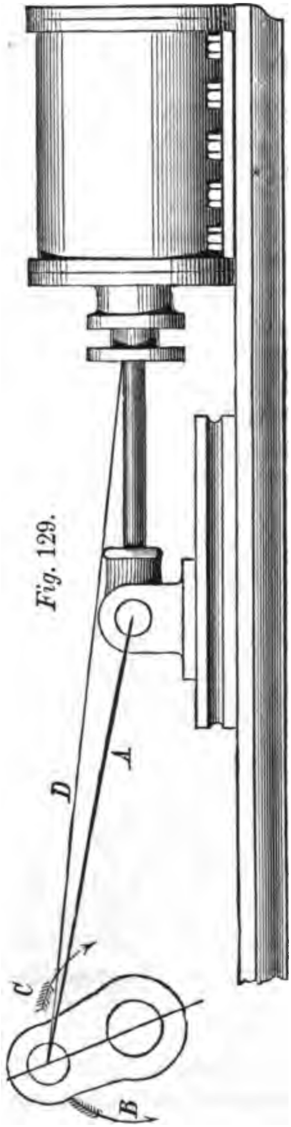


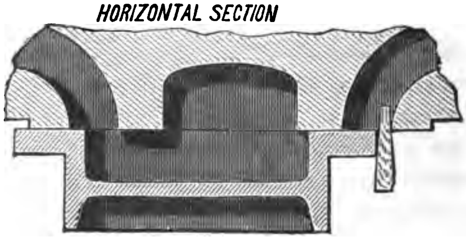
Fig. 129.

direction, but the spring of the various parts, the direction of which is determined by the direction of the strain, is sufficient, even when the engine is new, and hence, there is no play in the guide-blocks to (if the engine is running in the direction shown by the arrow C in Fig. 129) relieve the guide-bars of the friction due to the weight of the connecting-rod. The only objection to be advanced against running an engine in the direction to relieve the slides of the weight of the connecting-rod is, that in such case the wear of gibs of the cross-head will be mainly on the underneath side, and that, therefore, the play should be taken up on that side, and the set screws provided for that purpose will, on many engines, be somewhat difficult to get at.

Having determined, then, the direction in which the engine is to be run, we place our eccentric so that its throw line (K, in Fig. 124) will stand sufficiently in advance (in the direction in which the engine is to run) to let the front port open to the required amount of lead, and fasten it there with the set-screw. We then measure the amount of lead there is on the valve when the eccentric is so set, by chalking the faces of the wooden wedge, and inserting it in the opening or lead of the port, as shown in Fig. 130, putting it in between the edge of the valve and

Fig. 130.

HORIZONTAL SECTION



the edge of the port until it is a snug fit, but not forcing it in (which would compress the wood). When the wedge is

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home it should be moved edgeways, and then taken out, and the steam port edge will have left a mark on the wedge, evidencing how far the wedge entered, and therefore the precise amount of the lead at that end. We then move the wheel forward until the crank is on the other dead centre—that is to say, until the centre-punch mark No. 8 comes exactly even with the scriber point G—and try the wedge in the back port, and if it enters at the same distance as it did at the front port, the valve is set.

If, however, there is found to be more lead at one end than at the other, it demonstrates that the eccentric rod is not the correct length; if the front port has the most lead, the eccentric rod is too short, and *vice versâ.* Locomotives and other engines, in which the height of the main shaft will vary in its relation to the height of the cylinder according to the weight of the engine or its load (as of fuel, water, etc.), should have their valves set with the load on and the engine in its working position, or moved along the rail, instead of revolving the wheel with the engine lifted off the rail.

It is an excellent plan after an engine valve is set, to take the scriber G, in Fig. 124, and making it exactly 6 inches long from point to point (so that its length may always be known and remembered) rest one point on some part of the steam-chest, and in a centre-punch mark provided for the purpose, and with the other, mark a line on the slide-spindle, when the engine is on each dead centre. Then put a centre-punch mark on the slide-spindle. Thus with the gauge applied to the steam-chest and slide-spindle, the valve may be set, in cases of necessity, without taking the steam-chest cover off. It is better, however, to remove the steam-chest cover if circumstances permit.

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CHAPTER XX.

PUMPS.

PUMPS are commonly divided into three classes, the suction pump, the force pump, and the suction and force pump.

SUCTION PUMPS.

A suction pump causes water to raise itself, by relieving its surface of the pressure of the column of air resting upon it. The principle upon which it acts may be explained as follows:

The surface of all water exposed to the air has the pressure of the air or atmosphere resting upon it; if, therefore, one end of a pipe or tube be lowered into water, and the other end be closed by means of a valve or other device, and the air contained in the pipe be drawn out, it is evident that the surface of the water within the pipe will be relieved of the pressure of the atmosphere; and there will be no resistance offered to the water to prevent its ascending the pipe. The water outside of the pipe, still having the pressure of the atmosphere upon its surface, therefore forces water up into the pipe, supplying the place of the excluded air. The water inside the pipe will rise above the level of that outside of the same in exact proportion to the amount to which it is relieved of the pressure of the air, so that, if the first stroke of a pump reduce the pressure of the air contained in the pipe from 15 lbs. on the square inch (which is its normal pressure) to 14 lbs. per inch, the water will be forced up the pipe to the distance of about 2¼ feet, because a column of water

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an inch square and 2¼ feet high is equal to about 1 lb. in weight.

It is evident that, upon the reduction of the pressure of the air contained in the pipe from 15 to 14 lbs. per square inch, there would be (unless the water ascended the pipe) an unequal pressure upon its surface inside as compared to that outside of the pipe; but in consequence of the water rising 2¼ feet in the pipe, the pressure on the surface of the water, both inside and outside, is evenly balanced (taking the level of the outside water to be the natural level of the water inside), for the pressure upon the water exposed to the full atmosphere will be 15 lbs. upon each square inch of its surface; while that upon the same plane, but within the pipe, will sustain a column of water 2¼ feet high (weighing 1 lb.) and 14 lbs. pressure of air, making a total of 15 lbs., which is, therefore, an equilibrium of pressure over the whole surface of the water at its natural level.

If, in consequence of a second stroke of the pump, the air pressure in the pipe is reduced to 13 lbs. per inch, the water will rise up it another 2¼ feet, and so on until such time as the rise of the column of water within the pipe is sufficient to be equal in weight to the pressure of the air upon the surface of the water without; hence we have only to determine the height of a column of water necessary to weigh 15 lbs. per square inch of area at the base of the column to ascertain how far a suction pump will cause water to rise, and this is found by calculation or measurement to be a column nearly 34 feet high. It becomes apparent, then, that, however high the pipe may reach above the water level, the water cannot rise more than 34 feet up the pipe, even though all the air be excluded within the pipe, because the propelling force, that is, the atmospheric pressure, can only raise a column of water equal in weight to itself. It is found, however, in practice, to be an excellent suction pump which will raise water thirty feet.

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From this it will be perceived that the terms "drawing water" and "suction pump" do not accurately represent the principles upon which this pump performs its duty; and it would be much more proper to call it a "displacement pump," since its action is simply to enable the water to rise by displacing the air from its surface.

The duty of this pump is, therefore, in the first place, to extract the air from the suction pipe, and, in the second place, to discharge the water from its barrel through the medium of valves in such a manner that the column of water in the suction pipe is at all times entirely excluded from the pressure of the atmosphere.

FORCE PUMPS.

A force pump is one by means of which the water is expelled from the pump barrel and through the delivery pipe by means of the mechanical force applied to the pump piston or plunger; the amount of power required to drive such a pump will, therefore, depend at all times upon the height to which the water is required to be forced. When a pump is arranged to draw the water, and force it after it has left the pump barrel, it is termed a suction and force pump; but if the water merely flows into it in consequence of the level of the water supply being equal to or above that of the top of the pump barrel, it is termed simply a force pump. Hence a suction pump performs its duty in causing the water to rise to the pump, a force pump is one which performs its duty in expelling water from its barrel, and a suction and force pump is one which performs both duties alternately.

All pumps require a suction and a discharge valve, the suction valve being so arranged as to open to admit the water into the pump barrel while the pump piston or plunger is receding from that valve, and to close as soon as the plunger stops or reverses its motion. The delivery valve is so arranged that it closes as the pump plunger or

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piston recedes from it, and opens when the same approaches it. When, therefore, the pump piston recedes from the suction valve, the latter opens and admits the water; and when the piston reverses its motion, the suction valve closes, and the descent of the pump piston forces the water through the delivery valve, that being its only possible mode of egress from the barrel of the pump.

The arrangement of the valves may be the same for a force as for a suction pump (although it is advisable, in some cases, to place an additional valve to a force pump to prevent the pump piston from receiving the force of the water in the delivery pipe), the only difference being that the water is permitted to flow freely away from a suction pump, whereas it is confined to the delivery chamber or pipe in a force pump, so as to force it to the required height or pressure, as the case may be.

PISTON PUMPS.

A piston pump is one in which the water is drawn or forced by means of the piston fitting the barrel of the pump air-tight, which is most commonly done by providing the piston with two cupped leathers, formed by being pressed in a die made for the purpose. The leather is soaked in the water before being placed in the die, and is allowed to remain in the die until it is dry, when it will be sufficiently hard to admit of being turned in the lathe.

The capacity of a piston pump is its area multiplied by the length of its stroke; but it must be remembered that all pumps throw less water than their capacity, the deficiency ranging from 20 to 40 per cent., according to the quality of the pump. This loss arises from the lift and fall of the valves, from inaccuracy of fit or leakage, and in many cases from there being too much space between the valves and piston or plunger.

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A plunger pump is one in which a plunger is used in place of a piston, the gland through which the plunger moves serving as its guide, and also keeping it air and water-tight. The plunger is made smaller in diameter than the bore of the pump barrel, so that the capacity of such a pump is the area of the end face of its plunger multiplied by the length of its stroke, because the pump acts by reason of the displacement caused by the plunger entering the barrel. Pump-plungers should always be draw-filed lengthways to prevent them from wearing away the packing so rapidly. It is always advisable in this kind of pump to allow as small an amount of space between the plunger and barrel as possible, for the following reason: When the plunger becomes worn, it is necessary to turn it up again in the lathe, thus reducing its diameter. The result is that there is so much air in the pump, between its barrel and the plunger, that it expands as the plunger leaves the barrel and is merely compressed by the plunger returning, so that the pump becomes very ineffective, and finally ceases to pump at all. If the pump, in such a case, be primed with water each time it is started, it may draw water, but not to its full capacity, as the air will remain in the pump barrel until such time as it may become absorbed by the water.

Suction valves for all pumps should be made as large in area as it is possible to get in, so that they will not require to lift much to admit the water to the pump: since it is evident that, when the piston or plunger commences to descend and the suction valve to close, the water passes back through the suction valve until it is closed, thus diminishing the effectiveness of the pump, and, further, causing the valve to close with a blow which proves very destructive to the valves, especially of fast-running pumps.

The area of the opening of a suction valve must be at least equal to the area of the suction pipe, whose area is determined by the following principles: Water will not

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flow through a suction pipe in a solid stream at a greater speed than that of 500 feet per minute. It follows, then, that, the quantity of water the pump is required to throw being determined, the suction pipe must be of such a size that 500 feet of it will hold such quantity.

If the suction pipe be any smaller than that size, the pump will not be fully supplied with water; and the piston or plunger travelling faster than the supply of water follows it, there is, when it arrives at the end of its suction stroke, a partial vacuum in the pump barrel, which keeps the suction valve open. When the piston or plunger has descended until it strikes the water again (the suction valve not having yet closed), the water, descending with the piston, strikes the suction valve with a blow, which, as before stated, gives a backward impetus to the water in the suction pipe, and closes the valve with a blow very destructive to it; especially is this the case in a force pump or a fast running steam pump, in which latter case the steam piston accelerates in speed (when the pump piston has the partial vacuum referred to in it) because not only is the steam piston relieved from performing any duty, but it is assisted by the vacuum; so that it accelerates its speed greatly until the piston strikes the water in the pump barrel, which it will do with such force as to very probably break some weak part of the engine or pump, or cause the crossheads or piston to become loose. If the working parts of any pump are accurately fitted, it will deliver more nearly its full capacity of water when running slowly.

An air-chamber placed in the suction side of any pump causes a better supply of water to the pump by holding a body of water near to it, and by making the supply of water up the suction pipe more uniform and continuous. Air-chambers should be made as long in the neck as possible or convenient, so that the water, in passing from the pump barrel to the delivery pipe, shall not be forced up

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into the chamber at each stroke of the pump; for the air in the chamber becomes gradually absorbed by the water. If fresh water is continually passing into and out of the chamber, the air in it will soon become absorbed, and water will supply its place; but if the air-chamber has a long neck, the water at its highest level in the chamber will remain there unchanged by the action of the pump, and will become impregnated with air, thus diminishing its propensity to absorb any more; and although the air will finally become all absorbed out of the air-chamber, the process is a very much slower one, the air-chamber being so much the more effective, and its elasticity, imparting a steady flow of water from the delivery pipe, being unimpaired.

Pumps whose pistons revolve are subject to the same defects from inequality of wear as are rotary engines, but the results are not so keenly experienced, because water will not leak through so rapidly nor to so serious an extent as steam, and, further, because the leakiness of the pump may be compensated for by an increase of the rotative speed of the piston.

Water will not, however, as before stated, flow through the suction pipe at a greater velocity than 500 feet per minute; so that, if the pump performs more revolutions than are requisite (according to its capacity) to carry off more than the quantity of water contained in 500 feet of its suction pipe, the power used in running those extra revolutions is lost, inasmuch as they are superfluous except for the purpose of compensating for the defects in the construction or leakiness of the pump, in which case the excess of speed becomes a necessary evil.

In actual practice it is found that the efficiency of a pump is appreciably increased by increasing the size of suction pipe to a diameter sufficiently large, that the water requires to travel through it at a speed of not more than 200 feet per minute. It is also found that the effective-

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ness of a pump varies with the height it draws the water, or in other words, the length of the suction pipe.

Prominent among the causes of the loss of efficiency in pumps appears to be the want of a comparatively large body of water close to the suction side of the pump. Supposing a single acting pump, such as plunger pumps usually are, to have a suction pipe capable of supplying as much water flowing through it, at a speed of 500 feet per minute, as the pump delivers per minute. In the first place, the water only flows through the suction pipe at and during the up stroke, so that the water will, in such a pump, have to pass through the pipe at a speed equal to 1000 feet per minute. So that the suction pipe for a single acting pump should be of such a size that it will deliver as much water flowing through it at a speed of 250 feet per minute, as the pump delivers per minute, in which case the water in the suction pipe will, while actually in motion, move at a speed of 500 feet per minute.

If, however, the pump is a double acting one, the suction pipe may be of such size that it will deliver, flowing through it at a speed of 500 feet per minute, as much water as the pump will deliver per minute, or in other words, the suction pipe should bear the same proportion in size to a single acting as to a double acting pump.

If a pump makes 60 strokes per minute, and the water flows through the suction pipe at the rate of 500 feet per minute, it is obvious that each stroke of the pump will draw the water from a length of over 8 feet of the pipe. Now it is a good pump which will deliver 80 per cent. of its capacity; allowing a loss of 10 per cent. for the lift and fall of the valves, we still have a loss of 10 per cent. unaccounted for, and it is self-evident that the column of water entering the pump must be broken somewhere, to a partial extent, at least, and it is reasonable that the break occurs close to the pump, because the water close to the pump has not the friction on the sides of the pipe tending to hold it

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back. Now, if a pump was provided with a reservoir (similar to a steam chest), and the suction valve was at the bottom of such reservoir, there would be very little liability of the pump failing to get a full supply of water, because the water in the reservoir would flow readily into the pump, and the break, if any, would be at the upper part of the reservoir, which break would, provided that the suction pipe entered the reservoir at the bottom, cause a continuous flow of water up that pipe, while at the same time the supply to the pump would not be appreciably affected by the break. An air-chamber on the suction side of a pump does not fulfil these conditions, because the orifice connecting the air-chamber to the suction valve is comparatively small, whereas the whole body of water in the proposed reservoir would be in full and unconfined communication with the suction orifice or port of the pump. If a large steam chest induces an initial pressure, to a steam cylinder, more approximate to that obtaining in the boiler, how much the more necessary is a similar chest or reservoir necessary to a pump, especially when it is considered how much greater is the inertia of water than that of steam.

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